MANAGEMENT and SILVICULTURE IN THE SPOTTED GUM FORESTS ON THE SOUTH COAST OF NEW SOUTH WALES

by

B. J. FURRER.

This thesis was submitted for the degree of Master of Science in the Australian National University.

August, 1971.

This thesis is the author's own work except where specific acknowledgment is given.

B. J. Furrer

B. J. FURRER.

ACKNOWLEDGMENTS.

I wish to record my thanks to my supervisors, initially Dr. R. G. Florence and then Dr. K.R. Shepherd during Dr. Florence's absence overseas.

My thanks are due to Mr. E. D. Parkes for advice and discussion on the financial comparisons of recreation and timber production.

I greatly appreciated the computer programming help received from Mr. K. J. Phillis.

I wish to thank the New South Wales Forestry Commission for the assistance and study leave granted.

I am grateful for the co-operation of all officers of the South Coast district office and the Bateman's Bay sub-district office of the N.S.W. Forestry Commission, which allowed my absence from duty.

I am indebted to Mrs. J. G. Heley for typing the thesis.

ABSTRACT.

At the present time the South Coast of N.S.W. is undergoing development and expansion in both tourism and the timber industry. Definition of management policy is required for the Crown's forests in view of the call to use forested areas for recreation as well as timber production.

The location of the spotted gum forests and their relationship to the study area north from Bateman's Bay is described. Forest types within the area are presented and the mosaic pattern of species distribution illustrated with examples. Possible explanations for the pattern are discussed.

The irregular forests are examined for their role as wood production units. Benandarah S.F., which was selectively logged and heavily treated by ringbarking, has few large useless trees. This is in direct contrast to the unlogged and untreated area chosen for study on Kioloa S.F. where a volume of only 13749 super feet was merchantable in a total of 42784 super feet. Diameter increment rates for the average Benandarah forest ranged between 0.12 and 0.14 inches per annum; total volume M.A.I. for an eleven year period was 198 super feet.

The effect of wild fire on survival and growth rates was recorded. Overbark measurements showing a decrease in size $2\frac{1}{2}$ years after burning did not reflect the positive underbark diameter increment.

Three even-aged spotted gum stands are described and the growing stock and increment rates discussed. The volume M.A.I. ranged from approximately 300 to 800 super feet per acre per annum, except for the years of extreme drought when very low or negative increments were recorded. The small diameter dominant trees with good quality crowns grew most quickly

and the data suggests 0.4 to 0.6 inches per annum would be feasible during the zero to 40 square feet basal area period of stand development. A yield table was derived.

Past silvicultural treatment methods were assessed to find whether satisfactory regeneration had resulted from the treatment. Under certain circumstances ringbarking cull trees, the group selection method, advance growth salvage and clearfelling have all promoted satisfactory regeneration when the site was not quickly over-run by wet sclerophyll weeds. In the wet sclerophyll types consistent failure due to the loss of the site to vines and weeds indicated the need for site preparation. Tractor methods were recommended in preference to fire.

Drastic treatment was required to improve the merchantable increment on the irregular forest. This type of treatment changed the character of the forest and it was no longer suitable for recreational use. If less stringent selection of the retained growing stock is made the remaining stand is more attractive.

In the forests not treated in the past, return to timber production required heavy treatment by tractor, and preferably jiffy pot planting. An economic examination of this system, using the Faustmann formula, showed a 3.5 percent return for sawlog production on an 80 year rotation with mining timber thinnings, and 3.8 percent return for mining timber only. In productive irregular forests the present net worth in favour of clearfelling and producing more sawlogs rather than continuing with the group selection system is approximately $90.00 per acre. The rise in tourism and recreation is expected to continue. Pressure for forested areas to be set aside from timber production for recreation will increase. The opportunities for, and the costs of, multiple use management are presented together with a working example developed for the Kioloa Management Area.

TABLE OF CONTENTS

LIST OF TABLES.

LIST OF FIGURES.

CHAPTER 1.

INTRODUCTION.

Development and expansion on the South Coast of N.S.W., particularly in tourism and within the timber industry have drawn attention to the need to define management policies for the forests. Definition is required for all Crown forests on the South Coast but in this thesis only one section will be examined in detail. This section is the spotted gum (E. maculata, Hook) forest lying between the escarpment and the sea; from approximately Ulladulla in the north to Bateman's Bay in the south.

The relationships of this study area to the whole spotted gum zone and the general forest estate on the South Coast are shown in Figure 1. This map also shows the location of the spotted gum zone in relation to the major centres of population, Canberra and Wollongong, and to areas dedicated or under consideration for National Parks.

The timber industry has occupied an important place in the economy of the South Coast for more than a century and is increasing in importance relative to other major South Coast primary industries such as farming and fishing.

The major market is based on sawn framing and light structural timber for the building industry in Wollongong and Sydney. Other markets include light framing timber used locally by the home building industry. This outlet in recent times has been boosted by the upsurge of recreation and many people choosing to retire in the area. Good grade timber is used for concrete formwork, tunnel shuttering and other constructional forms in the city based industrial boom.

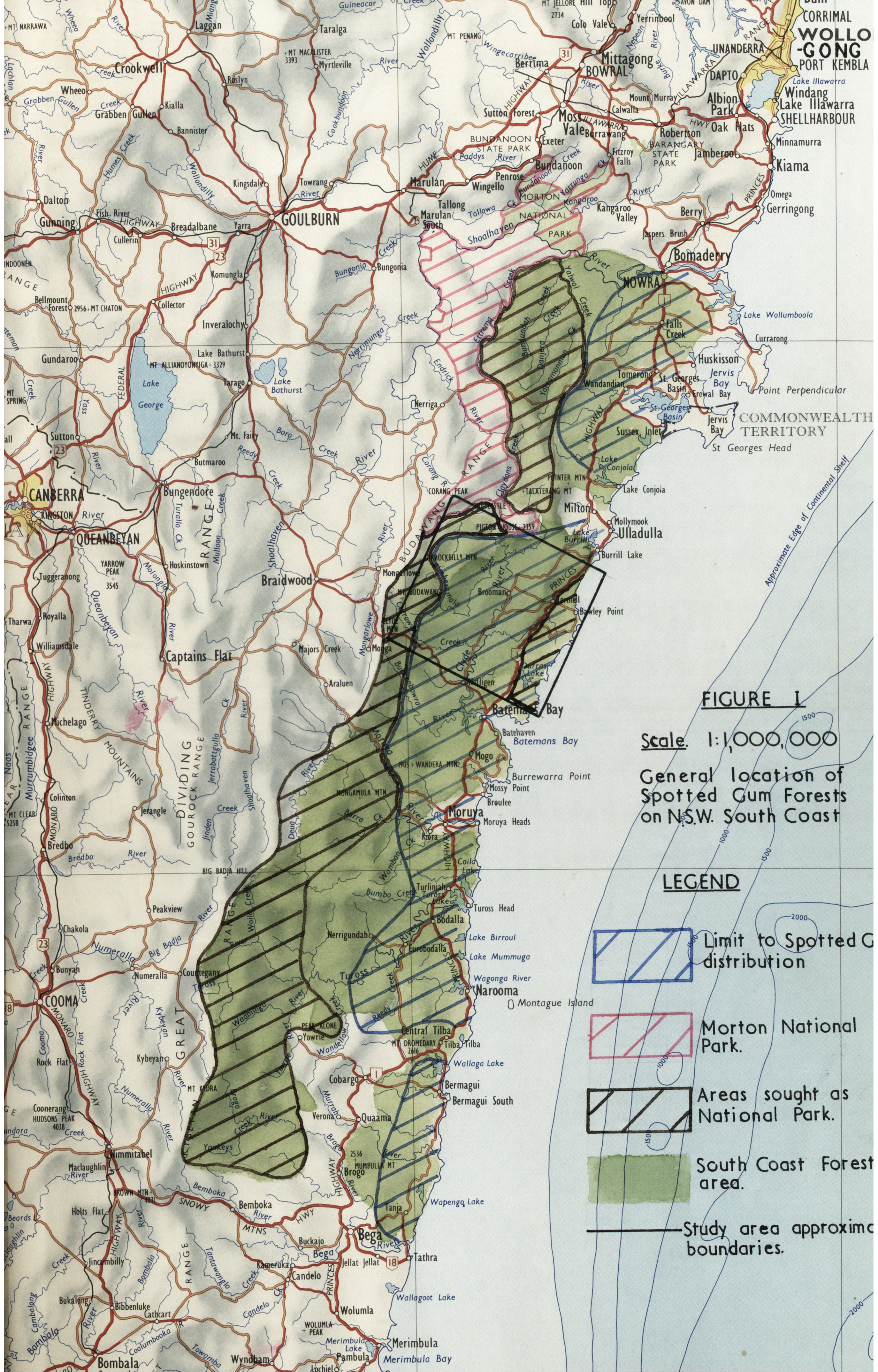


FIGURE I

Scale. 1:1,000,000

General location of Spotted Gum Forests on N.S.W. South Coast

The industrial timber market for the steel works and allied shipping companies is increasing. No longer are dunnage, crating and pallet timbers regarded as by-products of the housing market. Now they occupy end use positions in their own right. This allows utilization of lower average grade material than for the framing market. Expected expansion of the steelworks at Wollongong and the possibility of a new steel-making complex at Jervis Bay will create a substantial increase in the market for industrial timber. The small sized round timber used for mining purposes is being used in greater quantities with the expansion of the coal export market and production of this form of timber will be increasingly important. These increases could form a significant factor in the management and silviculture of the forests in the future.

With the large population centres of Wollongong and Canberra expanding, personal income rising and average working hours being reduced, increased use of the whole of the South Coast for outdoor recreation can be anticipated. The area occupied by the spotted gum forest includes part of the coastline and the adjacent gently sloping land. Apart from the attraction of the beaches the spotted gum forests have an intrinsic beauty of their own. The stately trees and picturesque understorey elements are highly favoured by all types of outdoor recreationalists. Past forestry activities have created a network of roads through the coastal and semi-coastal forests which further enhances the area for recreational use.

Anticipated pressure for increased recreational use in the future may require timber production forestry to be restricted or curtailed in some areas. Already amendments to established management plans, prepared principally for timber harvesting purposes, have been made for part of the Kioloa Management Area north from Bateman's Bay. The gentle topography and proximity to the Princes Highway makes the area most desirable for intensive forestry and in view of the increasing demand for mining and saw timber, continued production is required.

Production forestry and recreation are not necessarily exclusive forms of land use and it is possible for compromises to be reached so these and other forms of land use can occur simultaneously. However, the need for planning is most important. Conservation or political pressure groups should not foist multiple use on to forest areas now used primarily for timber production before first considering all the consequences of such a change in land use policy. Nor should forest management ignore the need for a flexible policy where compromise is required in multiple use situations. Silvicultural systems from clear felling to no felling are available as options depending on the management objective. This thesis examines and evaluates the ability of the various systems to provide acceptable management options for the forest estate.

CHAPTER 2.

ECOLOGY OF THE SPOTTED GUM FOREST.

2.0 General.

This chapter describes the location of the South Coast spotted gum forests, the climate, soils and geology of the area and the species types and distribution of the types within these forests.

2.1 Location.

The spotted gum forests are located in a discontinuous distribution from Nowra in the north to Bega in the south and from the ocean coast to a maximum distance of 20 to 25 miles inland. The species is restricted to the lower altitudes on gently sloping to moderate topography east of the tableland escarpment. Figure 1 illustrates the large variation in width of the zone. The bulk of the spotted gum forests occur in the block from Ulladulla to Bodalla. South from Bermagui the distribution of spotted gum types is dispersed by other forest types. The total area of the South Coast spotted gum zone, shown in this figure, is approximately 1600 square miles. The species range (Blakeley, 1955) extends from the general latitude of Maryborough, Queensland (25°S) to Bega N.S.W. (37°S). An isolated occurrence of small commercial significance is found in eastern Gippsland, Victoria, where it is known by the name "Mottled Gum".

The area investigated was reduced to the workable size shown in detail in figure 2. This section is located within the central part of the general distribution range and comprises the area from Bateman's Bay north to Termeil. The 20 mile square area is representive of the South Coast spotted gum types but minor changes have been known to occur in the larger area from Bega to Nowra.

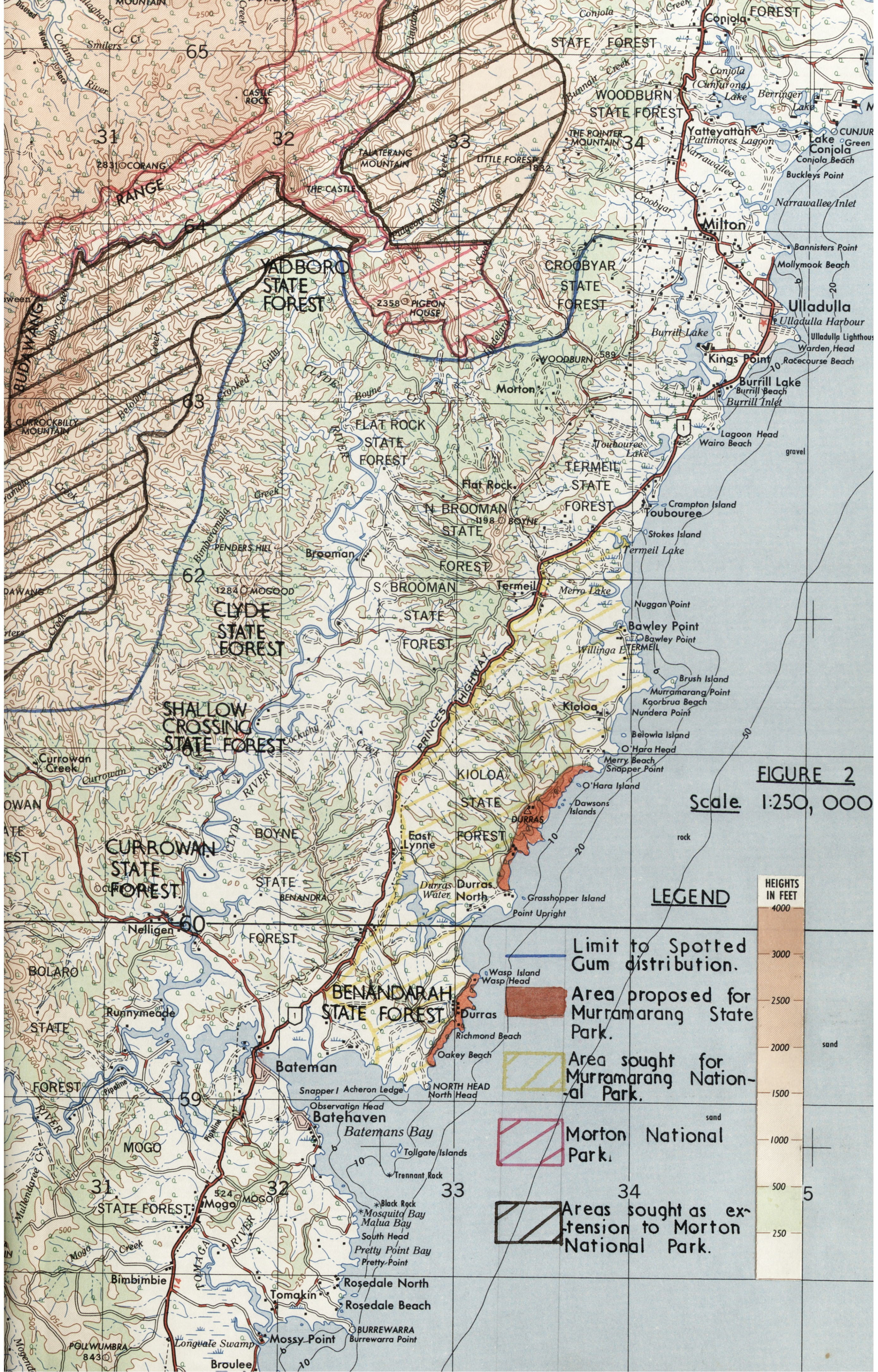


FIGURE 2
Scale 1:250, 000
LEGEND
Limit to Spotted Gum distribution.
Area proposed for Murramarang State Park.
Area sought for Murramarang National Park.
Morton National Park.
Areas sought as extension to Morton National Park.
HEIGHTS IN FEET
4000
3000
2500
2000
1500
1000
500
250
YADBORO STATE FOREST
WOODBURN STATE FOREST
CROOBYAR STATE FOREST
FLAT ROCK STATE FOREST
TERMEIL STATE FOREST
N. BROOMAN STATE FOREST
S. BROOMAN STATE FOREST
CLYDE STATE FOREST
SHALLOW CROSSING STATE FOREST
KIOLOA STATE FOREST
CURROWAN STATE FOREST
BENANDARAH STATE FOREST
CORANG
RANGE
CASTLE ROCK
TALATERANG MOUNTAIN
THE CASTLE
PIGEON HOUSE
THE POINTER MOUNTAIN
LITTLE FOREST
Conjola
Lake Conjola
Yatteyattah
Milton
Ulladulla
Ulladulla Harbour
Burrill Lake
Kings Point
Morton
Flat Rock
Brooman
Termeil
Tabourie
Bawley Point
Kioloa
Durras
Durras North
East Lynne
Nelligen
Runnymeade
Bateman
Batehaven
Batemans Bay
MOGO
Mogo
Tomakin
Rosedale North
Rosedale Beach
Mossy Point
Broulee
Bimbimbie
Point Upright
Grasshopper Island
Wasp Island
Wasp Head
Richmond Beach
Oakey Beach
NORTH HEAD
Tollgate Islands
Trennant Rock
PRINCES HIGHWAY
CLYDE RIVER
BUDAWANG
PENDERS HILL
MOGOOD
BOYNE
BENANDRA
BOLARO
Currowan Creek

2.2 Climate

2.2.1 Rainfall.

Rainfall for the central and northern part of the spotted gum zone varies between 35 and 45 inches (Water Resources of the Clyde Valley 1970). The southern section, south from Moruya, has a slightly lower rainfall of 30 to 40 inches (Water Resources of the Tuross Valley 1970).

Although the region lies in latitudes where uniform rainfall is expected, summer rainfall is generally higher than winter rainfall. A spring drought may occur through the months of August to November. August is usually the driest month receiving about 5 percent of annual rainfall. The wettest month varies from place to place in the area but is usually between January and April when between 2½ and 4 inches of rain can be expected.

Heavy storm rains may occur when an active depression is centred off the Coast. Falls greater than 12 inches in a 24 hour period have been recorded.

Extended periods of low annual rainfall are not uncommon. In the past, major periods of drought have occurred from 1901 to 1909, 1935 to 1942 and 1964 to 1968. During the latter part of 1968 drought the Clyde River ceased to flow at Brooman (Water Resources of the Clyde Valley, 1970). During these drought periods available soil moisture may be very low, resulting in complete cessation of tree growth, a point to be discussed in later chapters.

2.2.2 Temperature.

Temperature data for Nowra and Bodalla are given in Table 1. These two centres better represent the whole zone than Bateman's Bay or Moruya which are located on the Coast. The area within a mile or two of the sea has a significantly modified range of temperature due to the influence of the sea and the sea breezes.

TABLE 1. Temperature data

(i) NOWRA (Elevation 50 feet)

Average temperature (^{o}F) based on 16 years of record

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Average Maximum	81.3	81.1	78.3	73.0	67.1	62.4	61.9	65.2	70.1	74.9	77.2	79.6	72.7
Average Minimum	60.5	61.8	58.7	53.4	49.9	47.0	45.3	45.5	48.9	52.0	54.7	58.7	53.0
Average Daily	70.9	71.5	68.5	63.2	58.5	54.7	53.6	55.3	59.3	63.5	65.9	69.1	62.8

Highest on Record: 110.0^{o} F. Lowest on Record: 31.5^{o}F.

(ii) BODALLA (Elevation 40 feet)

Average temperature (^{o}F) based on 25 years of record.

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Average Maximum	76.2	77.6	75.4	71.1	66.5	62.9	62.1	64.0	67.5	70.2	72.2	74.9	70.0
Average Minimum	58.2	59.2	55.9	50.4	44.2	39.0	37.4	39.1	43.2	48.4	52.6	56.4	48.7
Average Daily	67.2	68.4	65.7	60.7	55.3	50.9	49.7	51.5	55.3	59.3	62.4	65.7	59.3

Highest on Record 113.0^{o}F. Lowest on record 25.5^{o}F.

Very hot days exceeding 100 degrees are recorded when dry north-west winds blow in the summer; 117 degrees was the maximum recorded at Bateman's Bay. Very high to extreme fire danger exists during these weather conditions.

2.2.3 Frost.

Frost occurrence ranges from nil to fifty per year depending upon topographical location and proximity to the Coast.

2.2.4 Wind.

Data on the speed of extreme wind gusts and the various return periods are reported in Water Resources of the Clyde Valley (1970) - Table 2.

TABLE 2. Speed of extreme wind gusts

Extreme Wind Gust (m.p.h.)	85	90	100	105
Return Period (years)	10	20	50	100

(from Water Resources of Clyde Valley, 1970).

Strong southerlies are generally associated with coastal storms and northwesterlies occur with the steep high pressure gradients ahead of a southerly change.

2.2.5 Fire, Weather and Bush Fires.

The condition of the unmanaged forest is largely dependent on its fire history. Management problems are often related to the problem of extreme and widespread fire patterns. Winds from the west and north-west during summer bring hot dry air from Central Australia and cause periods of extreme danger. When fires occur under these conditions suppression is extremely difficult if not impossible. For example, during the 1968 fire season large parts of the spotted zone were burnt. Fire danger rating on the McArthur scale exceeded 100 at one fire I attended; the situation was too dangerous to attempt control until the southerly change brought more humid air and lessening of the wind speed.

Although spotted gum is more resistant to death by fire than the other coastal species such as blue gum (E.saligna, Sm) and blackbutt, (E.pilularis, Sm), degrade of the forest occurs with all major fires. Fire, under the influence of the variations of humidity windspeed and drought, is a most important ecological and management factor.

2.3 Soils.

The classification of soils used with the forest type descriptions below follows Stephens (1956). The most detailed examination of soils in the study area was made by Walker (1960) who placed the spotted gum area under study into three major soil associations. (A soil association is a complex of soil families).

The two most important are the Mundaloo - Jamberoo association of prairie soils, these are reddish or yellowish prairie soils with some grey-brown soils on strong relief landscape of fine grained sedimentary rocks; and the Cumberland-Parma association comprised of red podzolics, yellow podzolics and red earths on fine grained sedimentary rocks where the relief is mild. The Nowra-Jamberoo association consisting of reddish or yellowish podzolics or prairie soils is of less importance.

The relationship between the soil classification system of Northcote (Northcote 1965: Atlas of Australian soils 1965) and the grouping of soil family based associations by Walker (1960) using Stephens (1956) classification by great soil groups is shown in Table 3.

TABLE 3. Classification of soils of the South Coast spotted gum forest.

Stephens (1956) Classification (as used by Walker (1960) to describe soil families on the South Coast)	Northcote (1965) as used in Atlas of Australian Soils (1965)
Reddish prairie soils	Friable red earths Gn 3.1
Prairie soils	Friable brown earths Gn. 3.2
Red podzolic	Duplex soil with hard setting surface and red clayey subsoil Dr. 2.2
Yellow podzolic	Duplex soil with hard setting surface and yellow clayey subsoil. Dy.3.4

2.4 Geology.

The geology of the Nowra to Bega area is contained on three Australia 1:250,000 Geological Series Sheets. They are Wollongong, Ulladulla and Bega.

The spotted gum forests are located on shales, slate, chert, sandstone and phyllite from three geological periods. The earliest are tentatively placed as Cambrian. Slate and phyllite from this time occur immediately both north and south from Bateman's Bay but its occurrence is limited. A major part of the zone, the central and southern section, is based on Ordovician sediments, these together with their igneous intrusions are located generally south from Termeil and a few miles inland from the Coast. Moruya "granite", tentatively placed in the Silurian, is found intruding into the Ordovician sediments from Currowan trig to Moruya. This "granite" carries spotted gum type, often in pure stands, as seen on the Braidwood road whereas no spotted gum occurs on the more recent monzanite at Milton and Mt. Dromedary. The monzanite has a high nutrient status.

In the northern part of the area spotted gum type is found on sandstones and siltstone of the Permian, Shoalhaven group, principally the Conjola formation and the Nowra sandstone.

2.5 Forest Types.

The spotted gum forest is characterised by a pattern of changing species, species associations, sub types and types. Baur (1965) established seven types within the "spotted gum league". Five of these are found on the South Coast. He defines a forest type as "any group of tree dominated stands which possess a general similarity in composition and character." The forest types used are based on ecological principles. They are not necessarily the climax form but except for this feature they are similar to ecological associations or groups of associations as defined by Beadle and Costin (1952). The "forest type" classification was primarily intended as an aid to forest management and for this reason Baur's classification rather than the ecological approach of Beadle and Costin is used in this work. The five spotted gum types found on the South Coast are :-

2.5.1. Spotted gum - Sydney blue gum or Bangalay type.

This type is composed of spotted gum and Sydney blue gum (E. saligna, Sm) as joint dominants in a wet sclerophyll forest with good height development. It occurs in the more favoured gully sites growing to 150 feet high. Occasional blackbutt (E. pilularis, Sm) and Woolly-butt (E. longifolia, Link and Otto) are found as minor associates. The understorey is usually a dense layer of rainforest shrubs and vines. The soils range from yellow podzolic at the upper levels to prairie soils on the lower slopes and gully bottom situations. Walker (1960) described the soils generally as "prairie soils".

2.5.2. Spotted gum - blackbutt type.

This type is less widely seen now due to selection logging prior to active forest management. Large stumps indicate widespread occurrence in the past. Spotted gum and blackbutt dominate the stand; blue gum and grey ironbark (E. paniculata, Sm) sometimes are present as minor species. The understorey is most commonly a moist shrub layer with a high proportion of wattle but this feature is highly variable. The type occurs away from the ridge top in the mid and lower slope position except where relief is afforded by major topographic features. The soils are yellowish podzolics.

2.5.3. Spotted gum - yellow stringybark type.

Spotted gum and yellow stringybark are the major species in this type although Mountain Grey gum (E. cypellocarpa L. Johnson) and woollybutt may also occur. It is usually a wet sclerophyll forest with dense understorey found on the higher altitude areas away from the coast. Baur (1965) describes it as the connection between the Messmate - Brown Barrel league and the spotted gum league. The type is found in the mid to lower slope position on podzolic soils derived from modified Ordovician sediments.

2.5.4. Spotted gum - ironbark type.

The spotted gum-ironbark type is located on well drained and shallow ridge soils generally upslope from the spotted gum, and spotted gum - blackbutt type, in the general mosaic. It forms a dry sclerophyll forest with minor xerophytic understorey shrubs and a grass layer. Best stand development is found on areas with mild relief. When the topography is steep the stands on the harsher aspects become stunted, restricted in size, and generally unattractive for commercial forestry. Red podzolic soils are found on the harsher sites but tend to yellowish podzolics on sites of lesser relief.

2.5.5. Spotted gum type.

This is a variable type in which spotted gum dominates the stand. It can range from a pure stand with various levels of association with other eucalypt species. The associates most frequently encountered are blackbutt, grey ironbark, blue gum, turpentine (Syncarpia glomulifera Sm - Niedenzu) (south to South Brooman State Forest the southern limit of turpentine distribution), yellow stringybark (E. meulleriana, Howitt), white stringybark (E. globoidea, Blakely) and mountain grey gum.

The understorey is variable, ranging from grass patches to a shrub understorey. Burrawangs (Macrozamia communis) often form a major part of the understorey.

Two major sub-types can be recognised; the first is the pure or practically pure spotted gum stand. An example of this type occurs on soils derived from silurian granite approximately 10 miles west from Bateman's Bay. The minor species in this area is maidens gum (E. maideni, F. Muell). Burrawangs are prolific in the understorey.

In the second subtype spotted gum occurs as a principal component within a complex mixture of associate species. This mixture of associates usually includes the species described in the types above and therefore to prevent confusion and mixing of the previously described types the stands are classified only on the principal species, spotted gum. The subtype is variable ranging from moderately dry to moist sclerophyll forest. Soils also are variable and range from reddish and yellowish podzolics to red and yellow prairie soils.

2.6 Distribution of forest types.

Complex distribution patterns exist both within the various spotted gum types, and between the spotted gum type and associations dominated by other eucalypt species. The variations are particularly important when forest management is considered. A typical distribution pattern is presented in figure 3. The figure illustrates the discontinuous nature of the types. The pattern broadly follows topography and the inherent differences in aspect, climate, moisture regime and soil characteristics associated with topography.

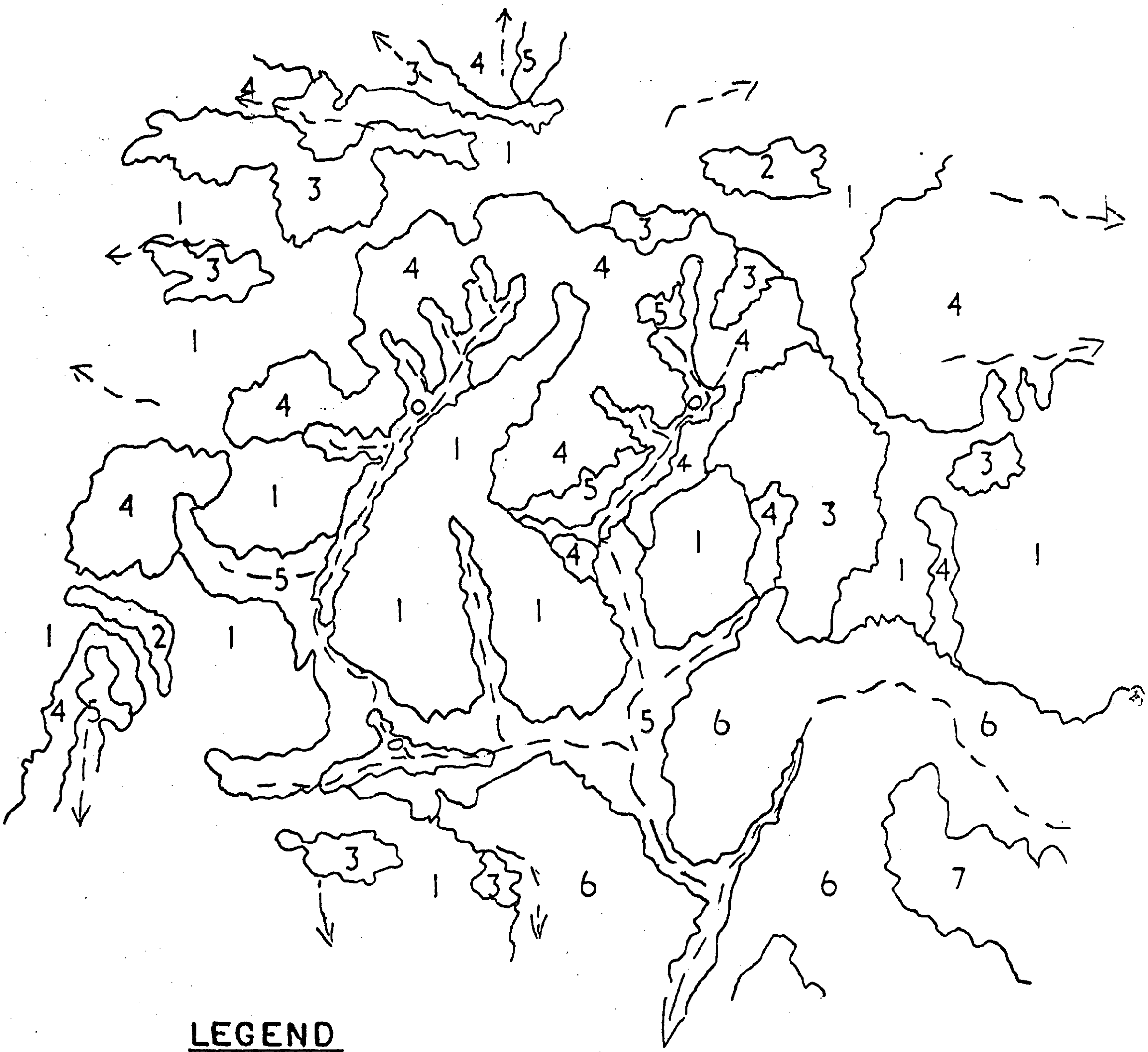
Spotted gum - ironbark forest is found on the ridges and upper slopes, more rarely in the gully. The spotted gum - blue gum type is usually in the gully. The various mixtures with blackbutt and other species occur on the slopes. The types without spotted gum as a component increase the complexity of the pattern. White stringybark - Sydney peppermint (E. piperita, Sm) and silvertop ash (E. sieberi, L.Johnson) occurs in large patches. Sydney blue gum, often hybridized with bangalay (E. botryoides, Sm) forms "pure" stands in gully situations.

Three measured examples are given to demonstrate patterns of forest types found in the study area.

FIGURE 3

An example of the complex distribution pattern of spotted gum types – South Brooman State Forest.

Scale: 1:15840



LEGEND

Type boundaries are shown: ————

Drainage pattern : — — — — →

Type O Brushwood species
1 Spotted Gum
2 Spotted Gum – Ironbark.
3 Spotted Gum – Blackbutt.
4 Spotted Gum – Blue Gum.
5 Blue Gum.
6 Sydney Peppermint – White Stringybark.
7 Bloodwood White-Stringybark.

2.6.1. Type distribution pattern, Benandarah State Forest.

The pattern of forest types was recorded for an easterly aspect over the slope ranging from ridge top to gully bottom. A series of transects was laid out at right angles to the ridge top and the trees were recorded by diameter over bark at breast height and by species. The transects ranged from eight to fourteen chains in length and to overcome the differences in total distance over the slope each transect was divided into eight equal sections. The stocking on a per acre basis was calculated for each section. The results are tabulated below in Table 4.

TABLE 4. Stocking per acre of trees recorded 4 inches d.b.h.o.b. and above on transects in Benandarah S.F. Each transect was divided into eight sections, section 1 in the gully and section 8 on the ridge top.

Species	Transect Section Number							
	1	2	3	4	5	6	7	8
Blue gum	27	22	25	18				
Spotted gum			40	15	25	30	33	24
Blackbutt				3	10	25	14	5
Ironbark				5	30	10	35	25
Species type classification	Blue gum		Spotted gum-blue gum		Spotted gum - ironbark type, except for transect section 6 which was spotted gum-blackbutt type.			

Blue gum occurs as a pure stand in the gully, this merges into a spotted gum - blue gum type on the lower slopes. With increasing distance upslope blackbutt and ironbark replace the blue gum. On the ridge the spotted gum - ironbark type is found; the type continues over the ridge on to the western aspect, not sampled in this study. The regeneration and understorey will be discussed later in Chapter 5.

2.6.2 Type distribution pattern, Yadboro State Forest.

The distribution pattern was recorded for an area on Yadboro S.F., this area is close to the western limit of the spotted gum zone. The major ridge system is oriented north east to south west and therefore the aspects involved are north west and south east, these two aspects have the greatest contrast. The data are easily simplified because in the sites selected each aspect was occupied by only one type. On the ridge top and the northwestern aspect the stand was a bloodwood (E. gummifera (Gaertn.)Hochr) - white stringybark type with occasional silver top ash; on the southeastern aspect spotted gum, white stringybark and ironbark occur. Once again the transects were divided into eight parts, section 1 close to the gully on the southeasterly aspect, sections 4 and 5 on the ridge top and section 8 close to the gully on a northwesterly aspect - Table 5.

TABLE 5. Stocking per acre in trees 4 inches d.b.h.o.b. and above on Yadboro S.F. Each transect was divided into 8 sections, section 1 close to the gully with a southeasterly aspect, sections 4 and 5 on the ridge top and section 8 close to the gully with a northwesterly aspect.

Species	Transect Section Number							
	1	2	3	4	5	6	7	8
Bloodwood				50	105	110	70	25
Silvertop Ash				10	35	25		
White Stringybark	25	30	20	15	70	75	90	40
Spotted gum	65	80	112	15				
Ironbark	43	27	34	40				
Species type classification	Spotted gum - ironbark type			Trans-ition	Bloodwood - white stringybark type.			

The soil, a pale reddish prairie soil, is similar on both aspects. However, increased rock fragments from the shale parent material and a lesser depth of the A horizon are recorded from the northwesterly aspect.

2.6.3 Vegetation distribution pattern - Boyne State Forest.

The third example uses data collected by students in the Ecology course of the Forestry Department at the Australian National University. The exercise was held on Boyne State Forest on land of moderate to steep topography. Roughly parallel transects (at right angles to the east west ridge), sampled the northern and southern aspects. The measurements were made at four equally spaced locations from gully to ridge top for each aspect. The results for each level on the slope were then pooled to represent zones of similar position on the slope. Each listed plot is based on data from seven separate transects spread over approximately 30 chains along the ridge top. The total area sampled is approximately 30 acres. The data in this form are set out in Table 6 and the distribution pattern is graphed on figure 4.

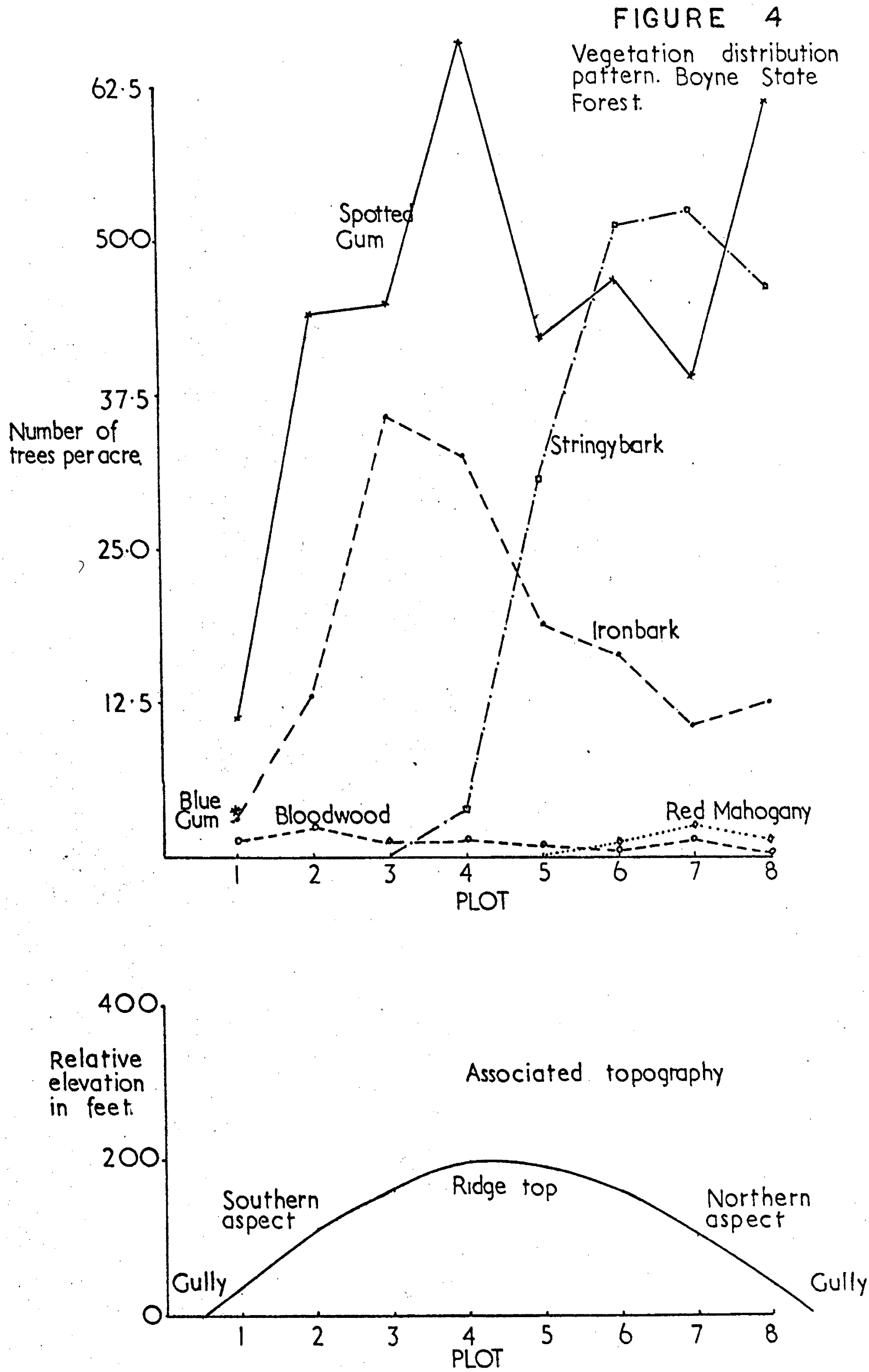


FIGURE 4
Vegetation distribution pattern. Boyne State Forest.
62·5
50·0
37·5
25·0
12·5
Number of trees per acre
Spotted Gum
Stringybark
Ironbark
Blue Gum
Bloodwood
Red Mahogany
1
2
3
4
5
6
7
8
PLOT
400
200
0
Relative elevation in feet
Associated topography
Gully
Southern aspect
Ridge top
Northern aspect
Gully
1
2
3
4
5
6
7
8
PLOT

TABLE 6. Stocking per acre in trees 4 inches d.b.h.o.b. and above on seven transects on Boyne State Forest. Each transect was divided into eight plots, plot 1 close to the gully on the southerly aspect, plots 4 and 5 on the ridge top and plot 8 close to the gully on the northern aspect.

Species	Plot numbers							
	1	2	3	4	5	6	7	8
Spotted gum	11.2	43.6	44.8	66.6	41.7	46.7	39.2	61.0
Ironbark	3.1	13.1	35.5	32.4	18.7	16.2	10.6	12.5
Bloodwood	1.2	2.5	1.9	1.2	0.6		1.2	2.5
Blue gum	3.7							
White stringybark				3.7	30.5	50.4	52.9	41.1
Red mahogany (E.pellita F.Muell)						0.7	3.1	1.2
Total	19.2	59.2	82.2	103.9	91.5	114.0	107.0	118.3
Species type classification	Spotted gum - blue gum	Spotted gum - ironbark			Spotted gum type			

A ringbarking treatment in 1925 and logging in 1959 - 60 does not alter the species distribution although the stand density is reduced slightly on the southern side.

White stringybark occurs only on the ridge top and northern aspect where numerically it exceeds spotted gum. Elevation may determine the relative numbers of the principal species on the northern slope but is not critical to species distribution. Despite the high numbers of white stringybark in the middle slope section of the northern aspect it is still classed as a spotted gum type as there are more large spotted gum trees.

Sydney blue gum occurs infrequently on the lower elevations of the southern aspect. This is the spotted gum - blue gum type. At higher elevations on the southern aspect the number of ironbark reach a maximum then start to decline as stringybark numbers rise strongly on the ridge top and northern side. The character of the ironbark forest is recognised in the classification given to this forest type, namely spotted gum - ironbark.

Rainforest elements occurred associated with blue gum on the lower southern aspect. At the transition between rain forest and sclerophyll seedling regeneration (smaller than 4'6" in height) and saplings (less than 6" in diameter but greater than 4'6" in height) were recorded in increasing numbers with increasing elevation. The lack of regeneration where rain forest understories are found is a general pattern and is discussed in more detail in Chapter 5.

The soils also vary from the southern gully to the ridge top and then on to the northern gully. At lower elevations on the southern side brown prairie soils support the spotted gum - blue gum type. This soil changes to have two quite separate horizons in the higher southern locations. The spotted gum ironbark occurs in this area. On the ridge top and down the northern aspect the soils are red and yellow podzolics, the yellow at the lower horizons toward the gully. Spotted gum type with its major associated species, white stringybark, occurs on the podzolic soils. The higher number of small white stringybark on the mid-slope northern aspects corresponds to areas of maximum drainage and very dry soils.

2.6.4 Factors affecting species distribution.

The pattern of vegetation on the South Coast is poorly documented. McColl (1965) is the only source of reference for the spotted gum zone. He examined sharply delineated ecotones between bloodwood and spotted gum and that between spotted gum and blue gum in an attempt to define the factors of the physical environment limiting the distribution of the species. In the area on Benandarah S.F. selected by McColl each of the four species associations studied were roughly related to topography. This pattern is not as clear on other areas, particularly where topography is less defined.

The four associations defined by McColl are the bloodwood association, usually on ridge tops; the spotted gum - ironbark and the spotted gum - blackbutt association located on the slopes; and the blue gum association in sheltered gullies.

A number of physical soil properties were investigated but all failed to account for the differences between the bloodwood and spotted gum associations. The bloodwood soils have a higher sand content and lower clay content, lower field capacities and permanent wilting points, narrower ranges of available moisture, less pore space and higher bulk densities than the soils supporting spotted gum. The ranges obtained for these soil factors all overlapped, however, and the soil moisture data may not be representive due to the study being carried out during a year of unusually high rainfall. Limitation of species distribution may occur only during times of high stress.

Again, chemical analyses revealed no significant differences between the paired sites in bloodwood and spotted gum types. The differences found suggest the soils supporting bloodwood are generally of lower fertility than those supporting spotted gum. The gradient found in most of the major nutrients reflects the general gradient from ridge to gully observed by both Baur (1957) and Florence (1963, 1964) in other Eucalypt forests where similar species distribution patterns are found.

Significant correlations were found between soil phosphorus and leaf phosphorus in the spotted gum association and soil calcium and both leaf calcium and bark calcium for the blood wood association. In conclusion, McColl suggests these correlations indicate differences in the nutrient uptake, and perhaps requirements, of the two species and thus the two associations are not supported by the same soil.

In addition to the Benandarah study McColl investigated a transect across an ecotone from pure bloodwood to pure spotted gum on Mogo State Forest. The parent material was granodiorite; the soil ranged from a grey brown or brown podzolic where the spotted gum occurred to a yellow or grey brown podzolic where the bloodwood occurred. Various soil properties were studied. Gradual changes in soil were related to changes in the Eucalypt association but these changes were not sufficiently sharp to denote a causal roll in the determination of vegetation pattern.

When blue gum soils were compared to spotted gum soils at Benandarah the blue gum was found on soils of higher nutrient content that those where spotted gum occurred. In addition, the blue gum soil has a high ratio of capillary to non-capillary porosity, indicating slow movement of soil moisture and poor soil aeration. Possibly restricted aeration excludes spotted gum from the wetter, heavier textured soils in the gullies resulting in pure stands of blue gum. The ecotone between blue gum and spotted gum is not always sharp as described by McColl. In fact, the two species co-exist over large areas and both in this thesis and the classification of forest types by Baur (1965) this mixture is recognised as a distinct type.

Failure to delineate significant differences in the physical environment of soils supporting the spotted gum and bloodwood associations leaves unresolved the question of limiting factors in the species distribution pattern. Florence (1963, 1964, 1965 and 1968) studied factors associated with the distribution of certain eucalypts on the Australian east coast. Spotted gum was not studied. However, there is the distinct possibility of similar relationships to those found by Florence for blackbutt and white mahogany (E. acmenioides Schau) existing between spotted gum, blackbutt, blue gum and ironbark on the South Coast and consequently the work is discussed below in more detail.

Florence (1964) investigated the edaphic factors responsible for the complex vegetational pattern in east coast forests and concluded differences in the geological pattern were responsible for some major features of the vegetational distribution. Examples are given where blackbutt forest is restricted to certain parent materials. Baur (1957) provides a further example in northern N.S.W. where a belt of blackbutt occurs on a soil with rhyolite parent material whilst the surrounding rain forest is on soil with basalt parent rock. Florence (1964) also speculated on the distribution of blackbutt and white mahogany as being due to different parent rock and soil relationships. Alternatively, he noted how on the same rock type there are many examples where physical properties of the soil appear to govern the distribution pattern and suggested distribution of blackbutt is limited by physical properties of the soil which restrict aeration, moisture permeability or penetration of the roots to depth. Thus nutritional levels appear not to be critical factors in the distribution pattern of the blackbutt - white mahogany type (Florence 1964) and for the spotted gum - bloodwood type McColl (1965). In the blackbutt - white mahogany association improved nutrient levels did not affect the relative distribution of the two species but rather the vegetational gradient tended towards rain forest.

Winterhalder (1963) measured approximately 129 + 39 p.p.m. manganese in the foliage of bloodwood and suggested the species is sensitive to soil manganese levels and is at a competitive disadvantage compared to other species where this element occurs in high concentration in the soil. McColl and Humphreys (1967) carried out further foliage analysis and found 130 + 13 p.p.m. for bloodwood and 476 + 62 p.p.m. for spotted gum. They suggest spotted gum may be more tolerant to manganese.

Cremer (1960), Gilbert (1963) and Mount (1964) discussed the distribution of Eucalypts and the inter-relationship with the distribution of rain forest. They considered fire plays an important part in the distribution pattern of the ash type Eucalypts found in Tasmania. Spotted gum trees are more resistant to fire than the ash type Eucalypts, deaths from fire are rare and for this reason the even aged regrowth stands common in the ash type are not found in the spotted gum forest.

The distribution patterns of the spotted gum types and the associated Eucalypt types are found in a predicable complex pattern related to topography but the factors which ultimately control the pattern are not clear. Strong argument can be made for the control being achieved by edaphic factors similar to the other East Coast Eucalypts discussed by Florence. Fire, however, is an integral part of the South Coast climate and its effect on species distribution is not known.

CHAPTER 3.

IRREGULAR SPOTTED GUM FORESTS AS WOOD PRODUCTION UNITS.

3.0 General.

The condition of the growing stock is an important factor in the management opportunity available for a forest. The site, the species, past management and treatment all have an influence on growing stock. Curtin (1970) has shown for blackbutt dominated coastal hardwoods the correlation between the level and quality of the growing stock and the opportunity to obtain a sustained yield.

3.1 The Condition of the Irregular Forest.

There is a wide range in the condition of the irregular spotted gum forest. The species type and site quality contribute to this range and these remain relatively unchanged under systems intended to retain the uneven aged irregular forest. The growing stock may be altered by management as logging and silvicultural treatment can alter stocking numbers, basal area and volume. Qualities of the growing stock are indicated by the stocking density, the vigour of the crown and the proportion of useless material in the boles. All these features have serious management implications and as a prerequisite to discussions of management opportunities the basic parameters and growing stock quality will be examined.

3.1.1. Classification of growing stock quality.

In the examination and comparison of the growing stock quality within and between stands the classification of dominance as defined by Smith (1962 p.33) has been adopted although the Crown class titles have been changed to those used previously in N.S.W. Smith's intermediate has been changed to sub-dominant and overtopped trees are termed suppressed. The classification is founded on the understanding that in both irregular forest and even aged stands certain trees have greater vigour than their neighbours in the stand. This situation perpetuates itself as competition becomes greater, for the more vigorous trees are likely to occupy the superior positions in the crown canopy and thus have the greatest chance for best growth in the future. Conversely the dominated become increasingly more dominated as their vigour is reduced. Position in the general canopy is therefore important in determination of the growth of the stand.

The vigour or condition of the crown can be classified as well as the dominance class. Three classes are used, generally referred to as crown class 1, 2 and 3. The classification is based on the activity of the crown as displayed by new growth and absence of dead or dying growth and the shape of the crown. The three classes are :

Crown class 1, the good crown, showing evidence of new growth and active crown expansion, a well balanced crown with no dead wood in the major section.

Crown class 2, the intermediate crown, showing little evidence of active expansion, often irregular in shape and with some significant deadwood in the major crown.

Crown class 3, the poor crown, showing crown reduction by the presence of fewer active leaves, often epicormic in origin, and with large numbers of dead and dying branches. Crowns in this class are often badly deformed and out of balance, caused by intense suppression from other stand members.

The third aspect of growing stock quality assessed is the relationship between useful and unmerchantable material. Each tree at measurement is allotted to a merchantability class. Three classes are used; classes 1 and 2 are useful, class 3 is useless. The division is sharp, but unfortunately the results do not reflect this precision. Trees are placed in class 3 when entirely unmerchantable; when partly useful the assessed tree is placed in either class 1 or 2. This classification does not indicate what proportion of the class is actually useful and the bole volume is used to overcome this problem.

The useful classes 1 and 2 were intended to separate trees for sawlog purposes from round timber, mining timber or poles. However, the two classes are combined due to the difficulty found in assessment practice to differentiate the mining timber removed as thinnings from the sawlog growing stock. The classification of trees into these merchantability classes is based on current 1971 standards of utilization and will require amendment with changes in the future. The current standards are considered to be high in comparison to general Eucalypt forest utilization. The industrial timber market centred on Port Kembla is the main reason for this high level of utilization. Based on the Forestry Commission of N.S.W. residual stumpage system sawlogs are sold with defect levels which reach 60 to 70 percent of the Hoppus volume. The minimum sizes for removal from the study area are 12 feet in length and 12 inches in diameter under bark at the small end. The log of both minimum length and diameter should be relatively straight and defect free.

Bole volume assessment is made from the natural bole length and diameter. The difference between bole volume and assessed volume indicates the quantity of the material not recognised in routine forest assessment. In old growth forest which has suffered from the effects of climate, fire and biological degrade, the useful length of the bole may only be a small proportion of the whole.

Many assessments are not interested in unmerchantable volume, but in others, where a clearer picture of stand condition is required, the following method allows assessment of both useful and useless material. The height to the natural limit of the bole is assessed. This is usually where major limbs of the crown limit the log. A merchatable log length is also assessed and from these two the total volume and the saleable volume can be derived. Thus an estimate of current stand quality or efficiency as future growth capital can be obtained.

3.1.2. Stand data calculation.

The basic data used in this thesis was compiled and calculated by computer at the A.N.U. Merchantable log lengths and diameter at breast height were used in a programme designed to calculate volume also increment rates divided by dominance classes and crown classes. Stocking numbers throughout the thesis will be in trees per acre (t.p.a.); basal area in square feet and volume in super feet Hoppus.

3.1.3. Check of volume table for small sized trees.

The volume table published in Tables for Forest Officers (Forestry Commission of N.S.W. 1966) has 8 inches diameter as the lower limit and therefore it was decided to check the volume table used in the calculation against a sample of trees measured from Benandarah forest.

For the check 51 trees between 5.6 inches and 14.0 inches d.b.h.o.b. were felled and measurements taken over and under bark up the bole to the merchantable limit. The data was processed by computer using a programme written by Phillis (1970) based on the graphical method and the Smalian formula. The programme provided individual tree volumes to particular merchantable limits. These could be used to form a volume equation which, if necessary, would apply to smaller trees whilst the usual "Silres" or "Hardass" equation of the Forestry Commission of N.S.W. was accepted for the larger trees.

This two volume equation approach did not prove necessary as the "Silres" equation fitted closely the trees felled and calculated in the sample and the new small tree volume table. Consequently the "Silres" equation -

$$\text{Volume} = 1.765 + \text{B.A.} \times (-25.0586 + 6.445 \times \underset{\text{Height}}{\text{Merch.}} - 0.02496 \times \underset{\text{Height}^2}{\text{Merch.}})$$

was used for all volumation.

3.2. The Irregular Spotted Gum Forest - Stand condition and growth Characteristics.

The quantity and quality of products created by a forest are greatly variable depending upon the species involved, the climate, the site factors and the growing stock. Emphasis is placed on the growing stock in the relationship to growth, yield and increment factors. Alteration of site and species by fertilizer and planting are possible but for the present, the growth of the spotted gum type forests on sites and under conditions currently existing on thousands of acres of State Forest is the issue in hand. The variations in growth rates produced by various degrees of silvicultural treatment which removes cull trees and promotes regeneration are studied.

Curtin (1970) discusses the productivity of irregular Eucalypt forests and it is against this background that the South Coast data will be presented. The similarity in growth and behaviour of many Eucalypts warrants this approach for in this way the deficiencies in South Coast data may be partly overcome by inferences from other species and location. Curtin notes records of growth rates in excess of 200 cubic feet per acre per annum on small growth plots but points out Jacobs (1955) stated "the greater part of the Australian native forest has deteriorated under a cut that has never exceeded an average of 6 cubic feet per acre per year."

Henry (1961) is more optimistic and expects the yield from managed forests in N.S.W. to be in the order of 20 to 25 cubic feet, improving with further treatment. Curtin (1970) presents a table listing average net yield since 1920, calculated sustained gross yield and useful growing stock for a number of forests and species in N.S.W. The past yield ranges from 3.0 to 33.6 cubic feet per acre per annum and the future sustained yield at 5.3 to 38.6 cubic feet per acre per annum.

The Kioloa Management Area, which comprises the major part of the spotted gum zone in the intensive study area, has a sustained yield of 8.4 cubic feet per acre per annum for the whole 95,000 acres. If the area is reduced to the productive forest area the yield rises to 12.8 cu.ft. per acre per annum. The yield and growing stock fit the lower area of the relationship shown by Curtin (1970) for useful growing stock and present sustained yield. From these figures he concludes the level and quality of the growing stock, despite a balanced distribution of size classes, is below that necessary for high sustained production. Henry (1961) forecast a sustained yield in spotted gum of 7 to 10 cubic feet whilst McGrath (1965) probably based on the drier, poorer spotted gum type common in Queensland forecast 5 cubic feet per acre per annum.

Examples are presented to show the range in growing stock and growth rates for irregular spotted gum forest within the study area.

3.2.1. An example from Benandarah State Forest.

The Benandarah State Forest has been selectively logged many times. Various forms of treatment have covered all areas at least once and some areas three times. The first treatment was in 1921. However, part of the area ascribed to that year was also shown as silviculturally treated prior to the 30th June, 1921. The 1921 treatment was primarily a cull ringbarking of the large veterans. Remnants of these rung trees and the stumps, often boarded up 15 feet for log felling, are still present. Little treatment was applied to the subdominant and suppressed members of the stand in these early days.

The second treatment, started in the mid-1930s, was also a cull ringbarking, but it removed smaller sized subdominant and suppressed trees as well as any larger useless material.

The third treatment round started in the mid-1950s. A deficiency in small sized trees was recognised by this time and the Australian group selection system was used in an attempt to overcome the shortage. The treatment continued following intermittent logging up until 1969, by which time the group selection system had undergone considerable modification and could only be described as a clear felling with seed trees. The effectiveness and suitability of the treatments are discussed in later chapters.

The plots for the spotted gum forest data were selected from the continuous forest inventory plots established on Benandarah State Forest in 1959. It is the only forest in the sub-district with plots established to determine general growth features in irregular forest. The few older growth plots are all established in selected prime stands with well above average site quality. The inventory was designed to cover the whole forest with plots on a 20 chain by 20 chain grid with a random starting point. The plots are quarter acre circular with a peg at the centre. At the time of establishment bias in the treatment of plots in relation to the surrounding forest was suspected and the plots were not marked conspicuously. An attempt at photo pin pointing was made but the lack of field marking resulted in only fortyone plots being relocated in 1965. Twentysix plots remeasured in 1971 for this study were selected from these. The plots selected had to satisfy two criteria; firstly, the number of spotted gum had to be greater than one third of the total plot stocking and, secondly, the stand had to be composed of one of the spotted gum types listed in Chapter 2. All stands which satisfied the numerical proportion did in fact belong to one of the spotted gum types. The distribution of the 26 plots into species types was :

13 plots - spotted gum type
7 plots - spotted gum - ironbark type
4 plots - spotted gum - blue gum type
2 plots - spotted gum - blackbutt type

The trees were assessed and classified into both dominance and crown classes. All plot data are combined as the small number of plots and the large variation between plots, and within species types prevented useful subdivision.

The stocking and growth data are summarised in Table 7.

TABLE 7. Summary of growing stock and increment rates - An example from Benandarah State Forest, for the period 1959 to 1971.

Merch. Class.	Dom. Class.	Stocking t.p.a.	Basal Area sq.ft.per acre	P.A.I.	D.b.h.o.b. equiv.for mean basal area - ins	P.A.I.	Assessed volume su.ft. H per acre	P.A.I.	Bole Vol. su.ft.H. per ac.
	1	2.1	8.7		27.6		1373	19	
	2	20.0	50.8		21.6		7377	101	
1 & 2	3	22.8	18.7		12.3		2225	46	
	4	4.8	1.7		8.1		161	2	
	All	49.7	79.9				11136	168	13981
	1	0.0	0.0						
	2	3.2	8.5		22.1		1169	9	
3	3	13.4	8.3		10.7		821	13	
	4	22.9	7.7		7.8		550	8	
	All	39.5	24.5				2540	30	3548
	1	2.1	8.7	0.11	27.6	.18	1373	19	
	2	23.2	59.4	0.74	21.7	.14	8546	110	
All	3	36.2	27.0	0.50	11.7	.12	3046	59	
Merch.	4	27.7	9.4	0.12	8.0	.06	711	10	
Classes	All	89.2	104.5	1.47	14.7	.11	13767	198	17529

The long history of treatment has been successful as the useful volume at 11136 super feet Hoppus per acre is 81.5 percent of the total stand volume within the plots. Further, no unmerchantable dominants and only an average of 3.2 co-dominants per acre remain. The removal of the larger useless stems was the primary aim of the treatment. Considerable numbers (36 per acre) of unmerchantable stems remain in the subdominant and suppressed classes. This is to be expected as silvicultural treatment to remove this material has only been carried out in that part of the forest logged in the last 10 to 15 years and any regeneration would not have reached 4 inches d.b.h.o.b. at the time of assessment, and so was not recorded.

The basal area of 104.5 square feet per acre is not excessive for a stand of this age and stocking composition and supported an increment of 1.47 square feet per acre per annum over the twelve year period.

The increment rates described in this section do not include ingrowth or mortality, very few trees crossed the 4 inch diameter breast height threshold and fewer still died. Trees removed during logging or treatment operations were similarly not included in growth calculations.

The diameter increment data are presented for the various species and size classes in Table 8 below :-

<u>TABLE 8</u>. Average annual diameter increment in inches.

Size Class d.b.h.o.b.

Species	4-8	8-12	12-16	16-20	20-24	24-28	28-32	32-36	36+
Spotted gum	$.08^{100+}$	$.12^{63}$	$.13^{34}$	$.14^{47}$	$.14^{29}$	$.12^{16}$	$.12^{11}$	$.06^{2}$	$.14^{2}$
Blackbutt	$.15^{23}$	$.22^{11}$	$.18^{6}$	$.32^{1}$	$.22^{1}$	$.20^{7}$	$.09^{1}$		
Ironbark	$.09^{50}$	$.12^{34}$	$.10^{21}$	$.11^{16}$	$.10^{7}$		$.02^{2}$		
Blue gum	$.24^{5}$	$.18^{10}$	$.16^{2}$	$.19^{4}$	$.28^{2}$	$.54^{2}$			
Other Species	$.09^{40}$	$.12^{14}$		$.13^{2}$	$.07^{2}$	$.24^{2}$			

The superscripts in Table 8 and Table 9 record the number of trees in each class and thereby indicate the reliability of the increment. This form of indicator for the reliability of the mean is used to overcome the absence of standard error information.

From the more reliable sections of the table an increment of 0.12 to 0.14 inches per annum for spotted gum, .15 to .22 inches per annum for blackbutt and .09 to .12 inches per annum for ironbark are the average growth rates. The 12 year period from 1969 to 1971 suffered both extremes of climate; extreme wet and floods during 1961 to 1963, and drought from 1965 to 1968. The drought caused periods of nil and negative increment, but it is not known if the periods of excess moisture increase the increment and thus balance out the drought, or further reduce the increment by a reduction in stand health caused by "wet feet" conditions and associated pathogens. Until shown otherwise the balanced out view will be adopted and the twelve year period accepted as "normal" with perhaps a slightly higher range of extremes than usual.

For the principal species, spotted gum, diameter increment rates were calculated for merchantability and dominance classes - Table 9.

TABLE 9. Diameter increment for Benandarah C.F.l. by size classes, dominance classes and merchantability classes.

		Size Class (inches d.b.h.o.b.)							
Dom. Class	Merch. Class.	4-8	8-12	12-16	16-20	20-24	24-28	28-32	32+
1	1					0.18^{5}		0.19^{3}	0.10^{1}
2	1		0.23^{5}	0.19^{8}	0.15^{32}	0.14^{20}	0.12^{15}	0.13^{15}	0.09^{3}
3	1	0.12^{31}	0.12^{27}	0.12^{17}	0.12^{11}	0.06^{2}			
4	1	0.06^{11}	0.05^{3}						
1	3								
2	3		0.21^{1}	012^{2}	0.04^{2}	0.17^{2}		0.03^{2}	
3	3	0.09^{18}	0.10^{15}	0.08^{6}	0.08^{1}		0.01^{1}		
4	3	0.03^{50}	0.06^{8}	0.05^{1}	0.12^{1}				
Crown Class	Merch. Class								
1	1	0.19^{2}	019^{4}	0.23^{4}	0.15^{8}	0.19^{9}	0.15^{7}	0.18^{5}	0.13^{2}
2	1	0.12^{25}	0.12^{25}	0.13^{18}	0.15^{34}	0.12^{16}	0.10^{8}	0.12^{3}	0.7^{2}
3	1	0.08^{15}	0.08^{6}	0.08^{3}		0.01^{2}			
1	3	0.33^{1}							
2	3	0.10^{11}	0.11^{2}	0.10^{6}	0.08^{2}	0.17^{2}		0.05^{2}	
3	3	0.03^{56}	0.07^{12}	0.06^{3}	0.05^{2}		0.01^{1}		

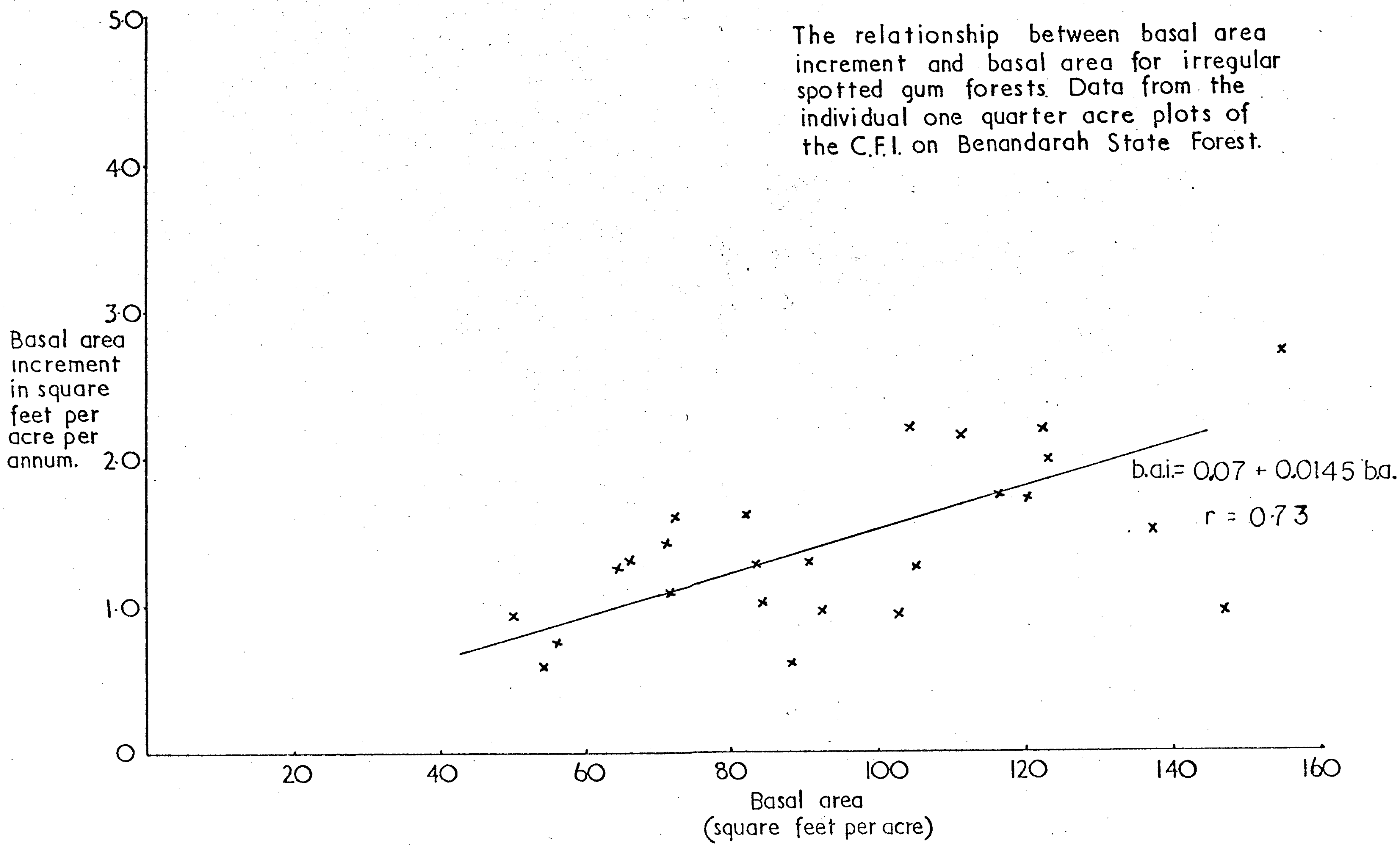
When the individual plot data are graphed (figure 5) the trend of total basal area increment increasing with total basal area is found. Henry (1960) reporting an experimental treatment series in spotted gum and ironbark also found variation in total basal area increment in relation to total basal area. The major contribution to basal area increment comes from the co-dominant section of the stand. It does however fail to produce an equivalent amount of basal area increment proportional to the 58.2 percent of standing basal area. The sub-dominant class appears more efficient.

When divided on a crown class basis the expected results occur; both the good and intermediate crowns produce a little more than their basal area proportion of the total. The poor class 3 crowns do not; 12.9 percent of the increment is produced on 18.5 percent of the basal area.

The yield and volume increment data is given in Table 7. The total average increment for all merchantability classes, was 198 super feet. The individual C.F.I. plot volume increments range from 53 super feet to 395 super feet per acre per annum. No relationship is readily apparent; when graphed against basal area the data is best described as a broad scatter pattern suggesting an increase in total volume with increasing basal area to about 120 square feet. This view is strengthened by a similar but more definite pattern shown when basal area increment is compared with basal area, figure 5.

FIGURE 5

The relationship between basal area increment and basal area for irregular spotted gum forests. Data from the individual one quarter acre plots of the C.F.I. on Benandarah State Forest.



In the subdivision based on dominance in Table 7, the co-dominant class fail to sustain increment equivalent to its standing volume, whilst the subdominant group improves its relative position. The useful stand produces 84.8 percent of the total increment. Bole volumes are included in Table 7 to indicate the total volume and allow comparison with the assessed merchantable volume. 36.5 percent of the total bole volume is not merchantable in this heavily treated forest, that is 6,393 super feet out of a total of 17,529 super feet per acre.

3.2.2. An example from Kioloa State Forest.

A nine acre block was subjectively located in an area chosen because of its undisturbed character. No routine forest operation had taken place in the past, the only evidence of logging was restricted to an odd blackbutt tree felled by sleeper cutters. Naturally, no silvicultural treatment had occurred. The area was not chosen to represent the Kioloa State Forest, which has a varied pattern of logging and silvicultural treatment, but as an example of unlogged and untreated forest. It is at the opposite end of the management range to the treated and logged stands depicted in the example from Benandarah State Forest.

The block is located in the spotted gum type with minor occurrences of blackbutt and white stringybark. Xeric shrubs and grass form the understorey and fire vines are present along the ridge top strip as a result of hazard reduction burning. Table 10 presents the Kioloa data.

TABLE 10. Summary of growing stock - An example of undisturbed, irregular forest, Kioloa State Forest.

Merch. Class.	Dom. Class.	Stocking t.p.a.	Basal Area Sq.ft.per ac.	D.b.h.o.b. equivalent for mean basal area - inches	Assessed Volume sup.ft. per ac.	Bole Volume sup.ft. per ac.
	1	1.9	20.0	43.9	2778	
	2	15.0	54.5	25.8	7846	
1 & 2	3	15.1	19.3	15.3	2210	
	4	8.6	8.5	13.4	915	
	All	40.6	102.3		13749	24314
	1	2.1	29.4	50.7	3843	
	2	4.1	27.6	35.1	3629	
3	3	21.2	20.4	13.2	1136	
	4	18.8	12.9	11.2	655	
	All	46.2	90.3		9263	18470
	1	4.0	49.4	47.6	6621	
All classes	2	19.1	82.1	28.1	11475	
	3	36.3	39.7	14.1	3346	
	4	27.4	21.4	11.9	1570	
	All	86.8	192.6	20.2	23012	42784

The most important features shown by Table 10 are the high basal area of the stand and the high proportion of this basal area assessed as unmerchantable material. A basal area of one hundred and ninetytwo square feet is considerably above the one hundred and five square feet suggested tentatively as ideal for the blackbutt forest by Curtin (1963). Almost half of this basal area is in useless trees which illustrates graphically the poor condition of the stand. When considered on a bole volume basis there is 29035 super feet of unmerchantable material. The useful assessed volume is 13,749 super feet per acre making 67.8 percent of total bole volume unsaleable. Only 5.9 trees per acre were classified as having a vigorous crown, 38.4 had a poor crown.

The volume is not considered abnormally high as in other parts of Kioloa where previous selection logging has occurred yields of 8,000 to 10,000 super feet has been obtained. This area was chosen to demonstrate a virgin or near virgin condition and not represent Kioloa State Forest. In areas west of the Clyde River yet to be opened up and logged, this situation is common and consequently any management decision must take account of the range of stand condition from the example given for Benandarah State Forest to the Kioloa example.

The dominant and co-dominant trees from Kioloa are significantly larger than those from Benandarah - Table 11.

TABLE 11. - Numbers of trees greater than 28 inches d.b.h.o.b.

Diameter (inches) class	28-32	32-36	36-40	40+	Total
Benandarah	3.2	0.6	0.3	0.0	4.1
Kioloa	4.2	1.6	1.1	3.5	10.4

Increment rates are not recorded for the Kioloa block in Table 10. Following subdivision into three approximately three acre plots different experimental silvicultural treatments were applied to the block. The details of treatment and increment are to be found in Chapter 5.

To emphasise the growing stock quality problem in management and treatment a further series of four, two and one half acre plots were established on Kioloa forest. The area was being logged at the time and the saleable products obtained and material left are recorded in Table 10. Two plots were located on both the northerly and southerly aspects; treatment followed logging.

TABLE 12 - Examples of residual growing stock - Kioloa S.F.
(Values on a per acre basis)

Type of Material or Product		Plot No. 1 (northern aspect)	2 (northern aspect)	3 (southern aspect)	4 (southern aspect)
Removed as Logs	No. of trees	8.4	12.8	8.4	12.8
	Basal area	36.5	52.3	35.6	52.0
	Volume	5870	7920	5648	9106
Retained Useful	No. of trees	14.4	10.4	16.8	9.2
	Basal Area	8.4	6.3	10.2	5.4
	Volume	approx 1000	approx 1000	1046	818
Removed in silvicultural treatment	No. of trees	60.1	28.4	44.0	30.4
	Basal area	63.1	62.3	86.7	60.8
	Volume	10741	8374	12937	11498
Total for plot.	No. of trees	82.9	51.6	69.2	52.4
	Basal area	108.0	121.9	132.5	118.2
	Volume	17611	17294	19631	21422

The logging approached a clearfelling as the only trees retained were useful stems less than 15 inches in diameter, and only small numbers of these trees were present. No saleable material was removed in the silvicultural treatment. The poor quality of the major part of the stand is reflected in the high proportion of growing stock removed in this follow-up treatment. The stands had received varying degrees of selection felling in the past, but no silvicultural treatment.

To support the opinion that the reduction in useless large trees on Benandarah State Forest was due to past treatment, the ringbarked trees and stumps as well as the living trees were recorded on an area subjectively selected to represent the average Benandarah forest. The measured area was 2.0 acres located in the central southern portion of Benandarah State Forest.

The basal area and numerical stocking is compared to the average data for standing trees on the Benandarah State Forest C.F.1 and with the undisturbed forest condition represented by the Kioloa block - Table 13.

The ringbarked trees on the measured area appeared to be the result of two separate operations, some culls looking distinctly older than the rest could be the 1921 treatment, whilst the second, 1936, treatment included the smaller useless trees. Close similarity in both numbers and basal area is observed between the reconstructed Benandarah area and the undisturbed Kioloa area.

TABLE 13 - Observation of treatment on Benandarah State Forest - Comparison with undisturbed forest on Kioloa State Forest.

	1	2	3	4	5	6	7	8
	Living trees Merchantability Class 1 & 2.	Living trees Merchantability Class 3.	All living trees (all merchantability classes)	Harvested trees - stumps only	Ringbarked useless trees	Total useful trees (Columns 1 and 4)	Total useless trees (Columns 2 and 5)	All trees
(i) Number of Trees per Acre.								
Treatment Study Plot	38	13	51	6	18	44	31	75
Benandarah C.F.I.Plots	50	39	89	Not recorded.				
Kioloa undisturbed forest block	41	46	87	0	0	41	46	87
(ii) Basal area of Trees								
Treatment Study Plot	76.0	27.8	103.8	32.3	51.0	108.3	78.8	187.1
Benandarah C.F.I. Plots	79.9	24.5	104.4	Not recorded.				
Kioloa undisturbed forest block	102.3	90.3	192.6	0.0	0.0	102.3	90.3	192.6

3.2.3 An example of growth on forest heavily logged but not silviculturally treated-Currowan State Forest.

In 1968 a 1.5 acre plot was established on heavily logged spotted gum type forest to obtain data on increment rates for the residual stand. The heavy logging was organised to obtain vigorous regeneration and so was not intended to retain better growing stock. All saleable material was removed leaving 52.5 square feet basal area and 35 stems per acre. The remaining trees, although classified as merchantable, were of particularly low quality. The residual stocking and growth data is listed in Table 14.

TABLE 14 - Stocking and Growth Data - heavily logged but not silviculturally treated forest - Currowan State Forest.

Crown class	Stand Function	Growing Stock in 1968 Merchantability Class		Periodic Annual Increment Merchantability Class	
		1 & 2	3	1 & 2	3
1	Number (t.p.a.)	Nil	.7		
	Basal area (sq.ft)	-	.1		0.04
	Diameter (inches)				0.82
	Volume (su.ft.)	-	2.5		1.4
2	Number (t.p.a.)	3.3	4.7	-	-
	Basal area (sq.ft)	4.1	16.9	0.22	0.36
	Diameter (inches)			0.37	0.26
	Volume (su.ft.)	456	2698	23	49
3	Number (t.p.a.)	8.0	18.0	-	-
	Basal area (sq.ft.)	8.2	23.2	0.44	0.74
	Diameter (inches)			0.33	0.23
	Volume (su.ft.)	601	2133	32	62
All Classes	Number (t.p.a.)	11.3	23.4	-	-
	Basal area (sq.ft)	12.3	40.2	0.66	1.14
	Diameter (inches)			0.34	0.24
	Volume (su.ft.)	1057	4831	55	112
	Bole volume (su.ft)	3320	10055	-	-

The growth rates on the plot are high in comparison to other irregular forest particularly in view of the large proportion of crown class three trees.

Basal area increment of 1.80 square feet indicates active growth and consequently active competition between the class 3 trees and the regeneration which had reached 15 feet in height by 1971. The total volume increment is 167 super feet per acre per annum, but only 55 super feet was saleable material. The removal of the class 3 material is imperative if full value of the regeneration of an area following logging is to be achieved.

The data however are for one plot in one location. Further study should be given to growth in the untreated residual stand as considerable areas are now logged and left untreated due to insufficient funds for fire protection and treatment.

3.2.4. Growth rates and the effect of fire on irregular spotted gum forest - Wandera State Forest.

Fires of varying intensity have occurred at irregular intervals throughout the spotted gum forest. For areas other than regeneration areas a policy of intensive hazard reduction burning exists.

The opportunity was taken following the widespread fires in 1968 to study the recovery and growth rates for spotted gum forest. The trees were individually selected in late 1968 from areas on Wanderra S.F. which were burnt by fires ranging from a typical hazard reduction burn to a severe crown fire. The trees were measured immediately following the fire before bark shed had started and again two months later, after bark shed, to indicate the loss in bark. At this time bark thickness was measured to allow underbark or true wood increment to be assessed. Bark thickness and diameter were recorded in 1971 together with an assessment of crown condition.

To categorise the recovery, five classes of damage were established at the first measure, immediately after the fire.

The classes of damage were :-

(i) Extreme, Crown removed by fire - leaves and small twigs consumed by crown fire.

(ii) Very Heavy, Very hot ground fire occurred sufficient to set the leaves in the horizontal attitude at the time caused by the high wind.

(iii) Heavy, Total crown scorch with the leaves normally oriented.

(iv) Moderate, Major part of the crown scorched although some crown "units" remained green.

(v) Light, Crown unaffected, forest floor burnt as occurs under hazard reduction burning.

The effects of the fires were assessed in 1971 using five classes :

1. Dead — Crown and bole dead.
2. Severe — damage still evident, epicormic growth on bole, branches dead.
3. Heavy — damage, smaller branches dead, epicormic crown on larger branches.
4. Light — damage, evidence of dead twigs remain.
5. Nil — No evidence of damage can be seen.

The current condition according to the above classification is recorded on Table 15 below.

TABLE 15 - Crown condition in relation to damage by fire - Wanderra S.F.

	Fire Intensity Class (1968)				
	Extreme (i)	Very Heavy (ii)	Heavy (iii)	Moderate (iv)	Light (v)
No. of trees 1968	22	26	20	12	9
Current crown condition based on evidence of damage(1971)			(Number of trees)		
1. Dead	2				
2. Severe damage	1				
3. Heavy damage	18	20	9	5	1
4. Light	1	4	8	3	3
5. Nil		2	3	4	5

Two trees died and one failed to reproduce a crown, all came from the crown fire area. All trees other than these three showed signs of recovery. The most common recovery pattern following complete crown scorch was epicormic shoots arising on the branches 2 inches in diameter or larger. The smaller dead branches remain. Classification becomes difficult in the lesser damaged crowns due to the interaction between natural crown degrade and degrade caused by fire.

Growth rates were calculated to include apparent growth in overbark dimension and the increment of underbark diameter by damage classes (Table 16).

TABLE 16. Increment functions following fire - Wanderra S.F.

Damage Class (1968)	Overbark increment from 1968 measurement immediately following burning to 1971 measurement. (whole period 2yr.6mth.)	True under bark diameter increment per annum (inches)	Percentage of crown made up from epicormic origin
1	- 0.25	0.28	85
2	- 0.33	0.17	60
3	- 0.24	0.25	33
4	- 0.11	0.18	27
5	- 0.31	0.22	11

For all damage classes the average overbark diameter $2\frac{1}{2}$ years after the fire is less than the diameter at the time of burning. However, during this period true wood diameter increment has continued and may even have been stimulated as increment rates are higher than corresponding increments in unburnt plots of the Benandarah S.F. Inventory. The crowns are comprised increasingly of epicormic growth as the intensity of damage from the fire increases.

The data are presented for two purposes, firstly to show how fires of moderate intensity can cause serious interruption to overbark volume estimates and secondly illustrate the true situation of continued increment in underbark, true wood volume following the fire.

Considering the integral part of the environment played by fire, either wild or controlled, the growth data shown by the Wanderra plots is encouraging. Defects being caused by burning are not well substantiated in the spotted gum forest.

Jacobs (1955) describes the effects of fire and the formation of gum rings causing degrade in timber quality. The pattern of gum vein production is not certain for following the 1968 fire a sample area was inspected in a heavily burnt stand defoliated by fire. No gum ring was found. The possibility of insufficient moisture being present in the tree for kino production was considered in the light of the harsh drought.

Other instances where burning has not caused gum veins are given by Henry (1965) for blackbutt and Podger and Peet (1965) for Jarrah (E. marginata Sm).

With the degrade situation not clear the process of hazard reduction burning should not affect total wood production despite apparent fluctuations in overbark volume. The long term effects from epicormic crown is not known but as routine hazard reduction does not envisage scorch of the major crown, this aspect will not affect protection burning.

The value of hazard reduction burning is discussed by McArthur (1967) who describes considerable forest losses due to wild fire and contends these could have been reduced by adequate protection planning. Bad fire seasons have occurred and will continue to occur at regular cyclic intervals. He considers protection will be achieved only by a dynamic policy of prescribed burning and consequently productivity will not be wasted nor will the stand condition deteriorate. In the same paper he outlines the various losses attributed to fire. These are losses caused by insects after fire damage, particularly termites, physical damage to the butt log and loss of increment and productivity due to death of stand members.

Using data from Jarrah (E. marginata Sm) produced by Podger and Peet (1965) McArthur suggests that rather than lose increment through control burning there may be an optimum fire intensity which will provide growth stimulus and increased productivity. With lesser intensity fires no influence on growth or log degrade are recorded.

3.3. Discussion on growth and stocking in the irregular spotted gum forest.

In the Benandarah State Forest after past treatment the merchantable dominants have diameter increment up to, but rarely exceeding, 0.2 inches per annum. The sub-dominant and suppressed fall to 0.12 and 0.06 inches per annum respectively. These are not good increments or encouraging results.

The increment rates in Table 9 are similar to the 0.11 inches average diameter increment found by Curtin (1969) for spotted gum on Yarratt State Forest near Taree. In the same paper he also records marked differences in growth rates between useful and useless trees in the same size class. The difference was apparent in all dominance classes. Similar differences are shown in Table 9 for the Benandarah data. Although insufficient merchantability class 3 trees occur in dominance classes 1 and 2 to make positive comparisons, in the subdominant and suppressed classes the differences are of the same order to those found by Curtin, namely 0.03 to 0.04 inches per annum. This difference in diameter increment by dominance class and crown class has been shown to occur in many east coast Eucalypt forests (Hoschke 1967) with data from Kendall M.A., Curtin (1969) using the Yarratt C.F.I.; and Phillis (1971) on Pine Creek S.F.) In each instance the increment rate tends to remain constant with increasing diameter through each dominance class or crown class but drops evenly between classes. The similar increment patterns for crown classes and dominance classes substantiates the observed characteristic of the dominant and co-dominant trees being those with the most vigorous crowns. Rarely in spotted gum forest do dominant trees have poor crowns or sub-dominant trees have class one crowns.

Florence (1969) discussing an examination made of a blackbutt forest on Pine Creek State Forest using similar crown classification to the one used in this thesis, accepts low crown vigour as the cause for decreased growth rates. However, at the same time, he suggests the basal area of 106 square feet per acre may be greater than the level able to sustain rapid diameter increment. If the basal area for Pine Creek forest is compared with the recommended values of Curtin (1963) and Jacobs (1955) for blackbutt forest, there is however, little evidence to support that 106 square feet was too high and should have caused the low diameter increment rates reported by Florence.

Thinned, even-aged spotted gum forest. Age 76 years.

This stand originated from complete clearing at the time of selection for grazing.

Termeil S.F.

Irregular spotted gum forest following ringbarking treatment and selective logging. Benandarah S.F.

CHAPTER 4.

EVEN AGED SPOTTED GUM FOREST

4.0 General.

Unlike the blackbutt, blue gum or ash forests the author has not found spotted gum in natural even aged stands. However, when spotted gum does, through some management technique, form an even aged stand similarity exists in the management advantages to be gained. Holmes (1968) gives examples of yield and growth for blackbutt in plantation form, he described it as "spectacular". Curtin (1970) quotes volume increments for even age plantation blackbutt, managed for pulp and sawlog timber, as ranging from 125 to 159 cubic feet per acre per annum. These figures when compared with Curtin's (1963) estimate for ideal irregular blackbutt of 80 cubic feet per acre per annum encourage an investigation of the even aged spotted gum.

The problem of thinning small sizes in even aged Eucalypt forest does not exist on the South Coast due to the active and expanding mining timber market. Virtually any tree between 6 inches and 11 inches diameter requiring removal can be sold.

Very few examples of even aged spotted gum forest exist. Three have established growth plots and these will be described. An attempt to make a crude yield table will follow.

4.1.1. Growth and stocking data from Benandarah spotted gum plantation.

On Benandarah State Forest an area was logged in 1941 and all the residual overstorey felled and burned. Part of the area was planted in 1942 with tubed spotted gum seedlings and one section was left unplanted. Natural regeneration has since become established on this unplanted section. At the same time an adjacent area of irregular forest was reserved as an example of the type of forest felled for the plantation.

In the planted area three plots were established in 1950 to observe the effects of thinning. An unthinned control plot had 450 trees per acre. A second plot was thinned to 305 trees per acre by removing all defective trees, trees interfering with others and the suppressed trees. No tree was removed "for the sole purpose of increasing espacement." The third plot was thinned to 170 trees per acre to conform with a recommendation for spotted gum made in South Africa which would supposedly allow free growth of the trees for the next five years.

At age 23, that is in 1965, the area was thinned for mining timber. Table 15 summarizes the stocking and other stand characteristics. No measurements were made of the material removed in the non-commercial thinning made at age 8 years. For comparison one plot was established in the area felled but left unplanted on which natural regeneration established.

TABLE 17. Summary of growth data for three planted blocks and one area of natural regeneration on Benandarah S.F. Two of the planted blocks were thinned at age 8. All three planted blocks were thinned for mining timber at age 23.

Age Years	Plot	Stocking t.p.a.	Diameter equiv.to basal area	P.A.I.	Basal area (Sq.ft)	P.A.I.	Volume Su.ft.H.	P.A.I.
	(a) Unthinned	405	7.93	0.34	139.0	6.0	19875	863
23	(b) Lightly thinned	305	8.71	0.38	126.2	5.5	18017	784
	(c) Heavily thinned	160	10.08	0.44	88.6	3.8	11487	498
	(a) Unthinned (1)	225	8.55	0.16	88.7	2.1	12632	410
29	(b) Lightly thinned	160	9.79	0.18	83.6	2.7	11683	404
	(c) Heavily thinned	85	12.15	0.22	68.5	2.3	9016	309
29	Natural regeneration (unthinned)	280	8.83	0.31	119.2	4.1	14600	503

(1) All plots thinned at age 23 for mining timber.

Useless material forms only a small part of the volume in the three planted areas; 5.9 percent, 2.4 percent, nil percent in the unthinned to heavy thinning respectively. In the natural regeneration area the unmerchantable material is 19.2 percent of the total.

The unplanted area restocked adequately. Records indicate the planted area was brushed in the early years to remove wattle and suckers which were probably the source of the natural regeneration. Wallaby damage was severe in the plantation.

The individual tree crowns were classified in 1971 and the subdivision is presented in table 18 below -

TABLE 18. Stocking numbers and volume subdivided by crown class for Benandarah plantation.

	PLOT					
	Unthinned		Lightly thinned		Heavily thinned	
Crown class	No. of trees	Vol. per ac.	No. of trees	Vol. per ac.	No. of trees	Vol. per ac.
1	50	7801	40	4749	60	7588
2	100	4232	90	6610	20	1362
3	75	598	30	323	5	66
Total	225	12631	160	11682	85	9016

The majority of the volume on all plots occurs on trees of crown classes 1 and 2, reflecting the lack of suppression in the stand.

Once again no statistical proof is available that these plots are sufficiently similar to allow the differences to be attributed to the different treatments as they were not replicated or allotted random treatment, but as they are adjacent to each other in an area selected for the plantation, comparisons can be made "with reservations". It is considered more useful to view the work in this light than to cast comparison aside for lack of statistical proof.

The area left unthinned in 1950 has produced the largest M.A.I. of the three treatments and the unplanted area. Total production, which is the commercial thinning yield plus the current volume, is 770 super feet per acre per annum for the 29 year period. The light thinning at age 8 yielded less at the 1965 thinning and also overall; the M.A.I. is 703 super feet per acre per annum. However, during the last six years the P.A.I. for the two plots has been the same. For the heavily thinned plot production is poorer. The crowns in this plot are bigger, lower, giving a shorter merchantable length, and more positively "broken" than the two adjacent plots presumably planted with similar stock. Volume M.A.I. at 460 super feet has allowed rapid diameter growth on the retained trees.

The basal area increment is lower for the heavily thinned plot, also the commercial thinning removed less basal area.

The trees destined for the major crop in later years are growing quickly. Increment rates exceeding 0.35 inches per annum are practicable for the first 30 years (Table 19)

TABLE 19. Growth rates for dominant and co-dominant trees, Benandarah S.F.

Area	Dominant and Co-dominant trees in 1971. (per acre) Number in 1971	Average Diameter 1971	Diameter Increment* 1942-71	1965-68	68-71
Unthinned at age 8 Commercial thinning at age 23 (1965)	110	10.61	.37	.20	.21
Thinned at age 8 to remove defective and suppressed trees. Thinned commercially at age 23.	125	10.53	.36	.16	.22
Thinned at age 8 to remove defective and suppressed trees also to space the dominant and co-dominant stand. Thinned commercially at age 23.	85	11.97	.41	.19	.24

* Note - 1965 to 1971 included a period of extreme drought.

No contribution to the 1965 yield was made by dominance class 4 trees, the smaller stands influence on total productivity is very small.

The yield from the other dominance classes is placed in Table 20.

TABLE 20. Production and yield from Benandarah Plantation by dominance groups.

Area	Unthinned	Lightly thinned	Heavily thinned.
1. VOLUME - Yield in commercial thinning at age 23			
Dom.class			
1	2221	662	1547
2	7371	6522	2445
3	114	1575	333
All classes	9706	8759	4325
2. BASAL AREA - Yield in Commercial thinning at age 23			
1	12.9	4.4	11.3
2	48.1	42.8	20.0
3	1.8	12.2	2.6
All classes	62.8	59.4	33.9
3. VOLUME - Total volume production up to age 29 years			
1	4619	662	1547
2	15795	14739	10752
3	1043	4919	1042
4	880	122	-
All classes	22337	20422	13341
M.A.I.	770	704	461

Both yield and total volume demonstrate the importance of the dominance class 1 and 2 trees in volume production for a young stand.

4.1.2. The even age spotted gum forest at Corunna S.F.

Corunna State Forest is located between Narooma and Bermagui and is therefore well outside the study area. However, on this small forest second growth spotted gum occurs in even aged stands. A set of thinning plots established in regrowth makes the area interesting and valuable in a study of even aged spotted gum forest.

The Corunna regrowth arose from regeneration treatment in 1916 and 1917. Widespread removal of the overstorey created the opportunity for regeneration to occur evenly over the forest although the area was not completely clearfelled and some trees remained after the treatment. There is no record of subsequent improvement treatment. The even-aged forest attracted attention in 1951 and a growth plot was established. Later in 1952, on similar country two thinning plots were established. On one thinning plot all the defective and suppressed trees competing with better quality trees were removed and on the second plot a heavier thinning schedule removed some co-dominant trees as well for increased spacing.

Comparisons between the thinned and unthinned areas are not made for whilst the two adjacent thinned plots are as far as can be judged similar in all respects the unthinned plot is not. The thinned areas are on a south to south easterly aspect and all trees were released by the 1917 treatment. On the other hand the unthinned area is on a west to south westerly aspect and had at least four trees of considerable size at the time of treatment. The thinned plot appears even aged whilst some irregular features are seen in the unthinned plot. However, as the treatment for the area was general and all plots are within a space of ten acres the data were presented together.

Each plot is one acre in size, being rectangular, five chains long by two chains wide. The stocking and growth data for the plots are in Table 21. The table is not subdivided on the basis of merchantability due to the small amount of useless material present.

TABLE 21. A summary of growing stock and growth data for the even-aged regrowth plots on Corunna State Forest.

Age	Area and respective treatment	No. of trees	Basal Area (sq.ft)	P.A.I.	Volume (super feet)	P.A.I.	Diam. equiv. to mean B.A. (inches)	Diameter P.A.I.
0-35	Unthinned	115	81.6	2.3	10772	308	11.4	0.33
	Lightly thinned	129	90.9	2.6	13801	394	11.4	0.33
	Heavily thinned	118	89.6	2.6	14662	413	11.8	0.34
35-47	Unthinned	114	105.0	2.0	13991	268	13.0	0.13
	Lightly thinned	99	100.3	2.3	16136	389	13.6	0.17
	Heavily thinned	71	84.2	2.2	15160	409	14.7	0.21
47-52*	Unthinned	112	107.4	0.5	14212	44	13.3	0.04
	Lightly thinned	99	104.1	0.7	16750	123	13.9	0.06
	Heavily thinned	71	88.3	0.8	15926	153	15.1	0.08
52-54	Unthinned	112	112.1	2.4	14978	383	13.5	0.10
	Lightly thinned	99	109.4	2.7	17628	439	14.2	0.15
	Heavily thinned	71	93.2	2.4	16799	437	15.5	0.20

*The period 1964 to 1969 included a time of extreme drought.

The Corunna area is a good example of even-aged stands on relatively low to moderate site quality. Diameter growth for the first 35 years averaged 0.33 inches per annum for the whole forest. In thinned plots the annual diameter increment of dominance classes 1 and 2 for the age zero to 35 years period is .39 inches for the lightly thinned and .36 inches for the heavily thinned plot. This fell significantly in the next twelve year period. Drought caused a marked decrease in average diameter increments to 0.04, 0.06 and 0.08 inches d.b.h.o.b. per annum for the unthinned, lightly thinned and heavily thinned plots. Dominant trees continued to achieve better increments even under the drought stress.

No significant reduction in stocking has occurred due to natural deaths in the suppressed section of the stand. In both thinned plots the dominant and co-dominant portion of the stand make up the major part of the total volume and basal area. In the unthinned stand trees in dominance classes 3 and 4 make up 42.2 percent of the total volume. The representation by dominance classes for stocking, basal area and volume is in Table 22.

TABLE 22. Sub-division of the even-aged stands by dominance classes at age 54 years - Corunna S.F.

		Plot		
	Dominance Class	Unthinned	Lightly thinned	Heavily thinned
Stocking (t.p.a.)	1	4	7	6
	2	31	36	47
	3	53	44	17
	4	24	12	1
	All	112	99	71
Basal Area (sq. ft.) per acre	1	12.7	14.3	12.8
	2	44.0	54.3	64.7
	3	46.4	36.7	15.3
	4	9.0	4.1	0.4
	All	112.1	109.4	93.2
Volume (super feet per acre)	1	2339	3103	2502
	2	6324	9160	11995
	3	5505	4938	2248
	4	810	427	54
	All	14978	17628	16799

When the quality of the crowns was classified in 1971, the following data resulted (t.p.a.) :

Crown class	Unthinned	Lightly thinned	Heavily thinned
1	19	25	22
2	55	40	41
3	38	34	8
Total	112	99	71

The low number of poor crowns in the plot thinned for good spacing reflects the removal of poor material in the thinning, and the release from competition given when the basal area was reduced to 57.2 square feet.

4.1.3. The even-aged stand at Termeil State Forest.

An excellent stand of even-aged spotted gum forest occurs on the No. 2 Extension of Termeil State Forest. A Forestry Commission of N.S.W. report dated 18th July 1939 describes the history and origin of the stand as follows "felled in 1895, leaving only a small part not touched. From 1895 the land felled was kept clear, some under cultivation, and the balance under pasture, some regrowth being allowed to survive and remain. This continued to 1910, following which year the block was allowed to remain uncared for." The reporting officer considered the stand originated in 1910. However, there is some doubt and the earlier date of 1895 is used to calculate the age of the stand. An uncleared area adjacent to this old selection carries the usual degraded cut-over forest.
In comparison to the irregular forest the even-aged stand looks most impressive, but when compared on the basis of tree height, aspect and soil, it would be average site quality.

Fortunately the character of the forest and the opportunity for an excellent growth study was recognised. A thinned plot and an unthinned plot, each of 0.875 acres, were established in 1945. The plots were exceptionally well documented, even to the extent of classification on a dominance scale for the trees removed at 1945. Re-measurement has occurred regularly since then and individual tree data recorded on each occasion. A summary is presented for the number of trees, basal area and volume each time the plot was rethinned and for 1969 and 1971 (Table 23.) Mortality and removals are also recorded.

Mortality in the unthinned plot appears to be limiting stocking density to about 140 square feet per acre. This natural thinning process has improved the stand as there are only 13 poor quality trees per acre present.

The thinned plot had a similar basal area and volume to the unthinned plot before thinning. In the thinning 161 trees yielded 7792 super feet of saleable timber and 129 trees were felled to waste. Even after this treatment at age 50 the plot contained 32 unmerchantable trees at the time of second thinning in 1963 at age 68. These were removed by silvicultural treatment.

TABLE 23. Plot stocking, basal area in sq. ft. and volume in super feet H. per acre for all trees in thinned and unthinned areas, Termeil S.F.

	Merch. Class.	Age 50	Mortality and Removals	Age 68	Mortality and Removals	Age 74	Mortality and Removals	Age 76
Thinned Plot								
No. of trees.	1	235	161	92	35	57	Nil	57
	3	148	136	32	31	1	Nil	1
	All classes	383	297	124	66	58	Nil	58
Basal Area	1	109.5	49.3	102.3	30.7	79.7		82.8
	3	39.1	27.7	16.2	15.0	1.1		1.2
	All classes	148.6	77.0	118.5	45.7	80.8		84.0
Volume	1	20196	7792	21796	6447	16880		17543
	3	4479	1896	3275	3082	243		254
	All classes	24675	9688	25071	9529	17123		17797
Unthinned Plot								
No. of trees.	1	149	Nil	149	Nil	148.6	1.2	147.4
	3	177	154	37	20	17.1	4.5	12.6
	All classes	326	154	186	20	165.7	5.7	160
Basal Area	1	96.2	Nil	136.8	Nil	136.1	.4	139.9
	3	48.7	35.3	15.0	7.6	6.7	1.6	5.1
	All classes	144.9	35.3	151.8	7.6	142.8	2.0	145.0
Volume	1	17470	Nil	25855	Nil	25913	32	26689
	3	4390	3255	2383	1167	1095	258	835
	All classes	22860	3255	28238	1167	27008	290	27524

<u>TABLE 24</u>: A summary of growth and yield data for the even aged thinned and unthinned stands at Termeil S.F.

Age and Period of data	Treatment	Number of trees	Basal Area (sq.ft. per ac.)	P.A.I.	Volume (su.ft. per ac.)	P.A.I.	Diameter equiv.to M.B.A.	Diameter P.A.I.
0 - 50 (1895-1945)	Unthinned	326	144.9	2.9	22860	447	9.03	0.18
	Thinned (prior to thinning)	384	148.6	3.0	24675	494	8.42	0.17
50 - 68 (1945-63)	Unthinned	185	151.8	0.4	28239	448	12.30	0.11 *
	Thinned	125	118.5	2.6	25071	535	13.26	0.17
68 - 74 (Drought) (1963-69)	Unthinned	166	142.9	minus 1.5	27008	minus 205	12.57	-0.07*
	Thinned	58	80.8	plus 1.2	17123	plus 215	15.95	0.13
74 - 76 (1969-71)	**Unthinned	160	144.9	1.0	27524	258	12.88	0.11
	Thinned	58	84.0	1.6	17797	337	16.30	0.15
	Total Production			M.A.I.		M.A.I.		
0 - 76 (1895-1971)	Unthinned		144.9	1.9	27524	362		
	Thinned		205.5	2.7	31792	418		

* All the diameter increment figures for the unthinned plot are for the trees alive in 1971.

** The increment period nominally 2 years was in actual fact 18 months, this would require the increments for the volume and basal area be raised by $\frac{1}{3}$.

Growth was greatly reduced during the severe drought from 1965 to 1968 but has increased in the two year period from 1969 to 1971. Due to mortality under drought stress the unthinned plot recorded negative increment for both basal area and volume.

The summarized growth and yield data are presented in Table 24. Basal area increment for the thinned plot of 2.7 square feet per acre per annum from the 76 year period is satisfactory. Volume M.A.I. for the thinned area, all merchantability classes, is 480 super feet per acre per annum, except for the drought years when it fell to 251 super feet per acre per annum. The M.A.I. for useful production is 418 super feet per acre. The unthinned plot has a lower M.A.I., the volume produced was 362 super feet per acre per annum and the basal area 1.9 square feet per acre per annum but mortality is not included in these figures.

When subdivided by dominance classes the volume and basal area growth has occurred primarily in the dominant and co-dominant trees. The sub-dominant trees have grown more slowly and the suppressed members have declined. This occurred naturally in the unthinned plot and was affected by thinning and silvicultural treatment in the thinned plot.

All trees standing at 1971 were classified according to the crown class definition presented previously (Table 25).

TABLE 25. Size and Volume Comparison for all trees in the thinned and unthinned areas, Termeil S.F. (Analysis by size classes)

	Crown Class.	1	2	3	All classes
	Plot				
Number of trees (t.p.a.)	Thinned	26.2	30.8	1.1	58.1
	Unthinned	28.5	49.2	82.3	160.0
Basal Area (sq.ft.per acre)	Thinned	46.7	35.8	1.5	84.0
	Unthinned	51.1	43.4	40.5	145.0
Mean B.A. per tree	Thinned	1.78	1.16	1.50	
	Unthinned	1.79	1.09	0.49	
Diameter equivalent to mean B.A. (ins)	Thinned	18.1	14.6	16.6	
	Unthinned	18.1	14.2	9.5	
Volume super ft.H.	Thinned	10291	7244	263	17798
	Unthinned	11309	10315	5900	25524
Mean volume per tree	Thinned	392	235	263	
	Unthinned	396	209	72	

Not only are similar numbers of trees present but also the average diameter,for class 1 trees, calculated from the mean basal area, is the same for both plots, i.e., 18.1 inches. This of course indicates similar growth rates.

Volume Increments are given in the table 26 below -

TABLE 26. Volume increment rates by crown classes - Termeil S.F.

Crown Class	Increment rates* 1895 to 1963 period		1963 to 1969 period (drought)		1969 to 1971 period.	
	Thinned	Unthinned	Thinned	Unthinned	Thinned	Unthinned
1	134	156	149	57	208	183
2	92	146	111	7	119	171
3	3	91	4	- 64	6	70
All classes	229	393	264	Nil	333	424

* The values in Table 26 are for trees alive in 1971. Trees removed at the 1945 and 1963 thinnings and those to succumb are not included. Good crowns have managed to retain their place in the unthinned stand despite the intense competition. This could be taken to indicate priority development for class 1 crowns irrespective of the fate of the subdominant and suppressed. Additionally it suggests growth activity of equal order for the crown 1 sections of stands with basal areas ranging from 70 to 140 square feet per acre.

Species other than spotted gum occurred in the natural regeneration which colonised the old farm. The total stocking in 1945, before thinning, divided by species into two groups, namely spotted gum and combined other species, forms table 27.

TABLE 27. Showing species breakdown of thinned and unthinned plots at Termeil. The assessment is made at 1945 prior to thinning and treatment in the thinned plot.

		Number of trees per acre	
Year	Species	Thinned plot	Unthinned plot
1945	Spotted gum	276	249
	Other species	107	77
1971	Spotted gum	55	146
	Other species	3	14

The proportion of spotted gum is increasing with time in both the thinned and unthinned forest. For the thinned forest this is due to thinning and treatment which was not based on the production of a pure spotted gum forest but had the stated aim of removing useless trees, unthrifty trees and trees with poor crowns as well as thinning the remaining stand to a set spacing. The high proportion of other species removed reflects the poorer quality of these trees.

In the unthinned stand the number of other species has decreased from 77 to 14 trees per acre. These trees have all died and selection toward pure spotted gum forest is proceeding. On a percentage basis the other species stocking numbers have fallen from 26.6 percent to 8.7 percent. Spotted gum appears to be more tolerant of stand competition than the other species which occur at Termeil, including blackbutt, white stringybark, red mahogany and ironbark.

The stocking on the degraded cut-over forest adjacent to the plots was assessed by measurement of trees within a one acre temporary plot. The assessment was made to illustrate once again the high proportion of unmerchantable growing stock in the degraded forest and to allow comparison with the even-aged stand grown after the original forest was felled. The stocking data are :-

	Number of trees per acre	Basal area per acre (sq.ft.)	Volume per acre (super feet H.)
Assessed as useful	52	53.0	5727
Assessed as useless	59	59.6	10241
Total	111	112.5	15968

The division of this stand by crown classes shows the justification of the word degraded. Only 10 trees per acre have class 1 crowns, 48 have class 3 crowns. The majority of the volume is in trees with class 2 crowns.

4.1.4 General comments on the growing stock of even-aged spotted gum forest.

The regular forest as shown by the examples at Termeil, Corunna and Benandarah, has a high percentage of useful stocking. The high proportion of crown class 1 and low proportion of crown class 3 indicates a beneficial level of crown vigour and growth.

For the one plot where suppression through excessive density was causing death, the active members of the stand appeared to be little affected by the dying members. In this stand selection by suppression was leading toward pure spotted gum forest.

The rates of diameter increment have been given for particular situations of age, numbers and basal area density, in the various sections dealing with specific areas. It is intended in this section to generalise, firstly the increments to be expected in various dominance classes and then the increments for various crown classes.

For the irregular forest it has been shown in the preceding chapter how diameter increment is relatively constant with increasing average diameter. For even age forests this feature is not found and the trend of decreasing diameter increment with increasing diameter is evident. Representive values have been used to create Table 28.

TABLE 28. Representive values for diameter increment by dominance classes and by crown classes for even-aged spotted gum forest.

	Diameter size class (in inches)						
Dominance Class	0-4	4-8	8-12	12-16	16-20	20-24	24+
1	.65	.46	.40	.30	.25	.22	
2	.55	.37	.28	.20	.17	.13	
3	.30	.24	.17	.13	.06		
4	-	.07	.07	-			
Crown Class							
1	.55	.40	.32	.23	.18	.14	
2	.35	.30	.19	.13			
3	.25	.10	.07	.09			

The size class distribution for even-aged forest usually follows the normal distribution pattern whilst the irregular form follows a logarithmic progression decreasing from the smallest size class to the largest. In Table 29 the frequency distribution for the even-aged forests is examined.

TABLE 29 - Size class distribution - Number of trees per acre - Even-aged spotted gum forest.

Forest Area	Diameter size class (in inches) 0-4	4-8	8-12	12-16	16-20	20-24	24+
* Benandarah Plant'n							
Not thinned	45	130	60	30	5		
Lightly thinned	15	55	65	40			
Heavily thinned	0	5	35	45			
Benandarah Natural Regeneration - prior to thinning	0	126	130	22	2		
Corunna							
Lightly thinned	0	10	26	37	24	2	
Heavily thinned	0	1	10	38	19	3	
Termeil							
Not thinned	0	28	52	51	19	8	
Thinned	0	0	3	28	21	6	

* Note : All the above areas have been thinned for a commercial mining timber operation subsequent to the original schedule.

The general pattern of rise and fall associated with the normal distribution is evident for all the areas in the table.

4.2 Examination of the Growth Functions and Extension of the Volume Data to produce a Simple Yield Table.

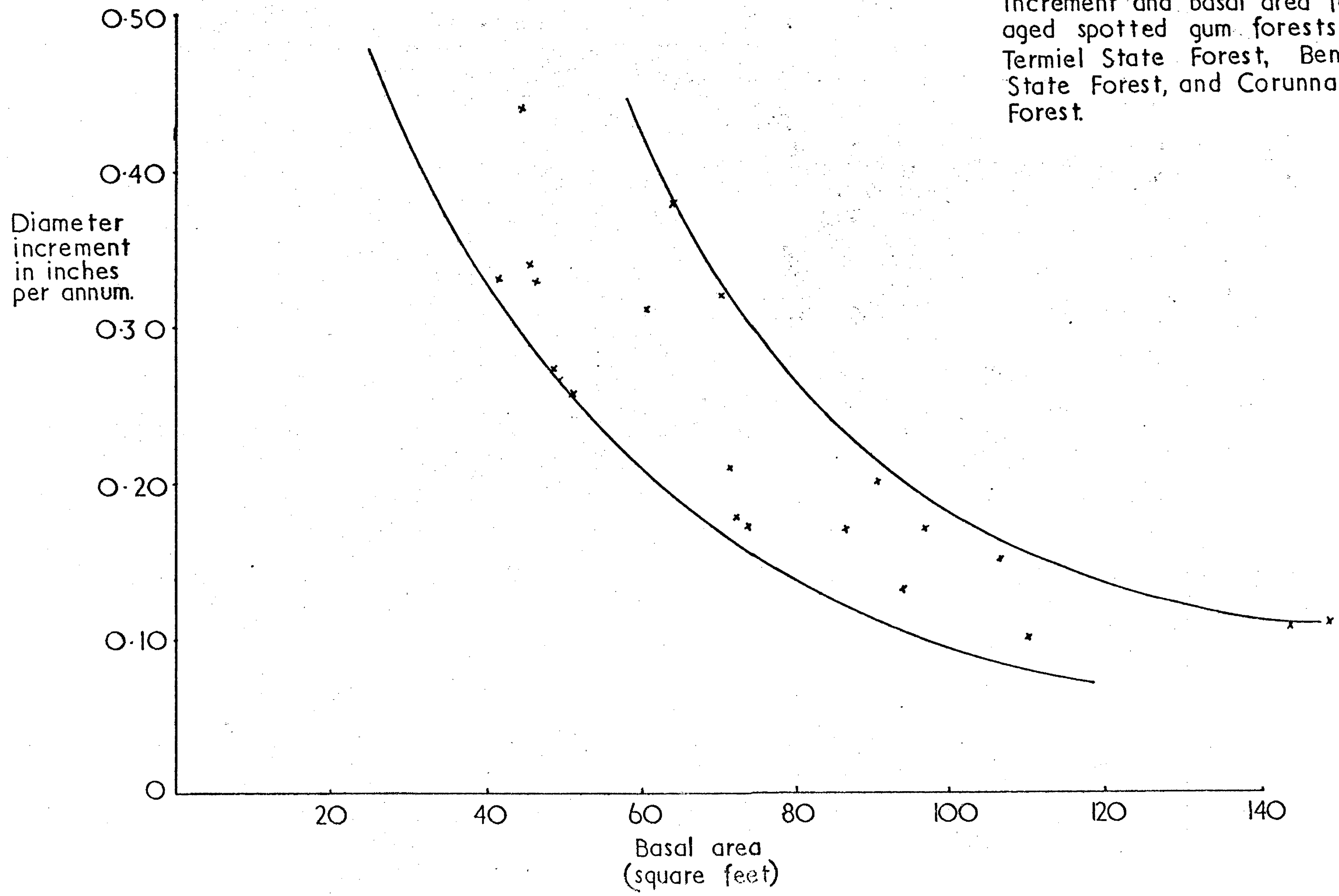
4.2.1. Growth functions of the even-aged spotted gum stand.

The specific yield and stocking data presented has indicated growth rate trends of decreasing diameter increment with increasing average diameter and increasing stand basal area. In all examples studied, and in all circumstances anticipated, numbers will also decrease as size increases either by thinning or through mortality.

The diameter increment data are graphed against stand basal area in figure 6.

FIGURE 6

The relationship between diameter increment and basal area for even aged spotted gum forests at Termiel State Forest, Benandarah State Forest, and Corunna State Forest.



The general limits associated with the three areas studied are proposed by the lines enclosing the data. Lack of examples in the first ten year period prevents continuation to an upper limit, however extrapolation suggests the increment rates of 0.6 inches per annum or better would be feasible for the zero to 40 square feet basal area period in stand development. This is supported by Table 28, for during this period virtually all trees would be classed as dominance 1 or 2.

4.2.2. The Yield Table.

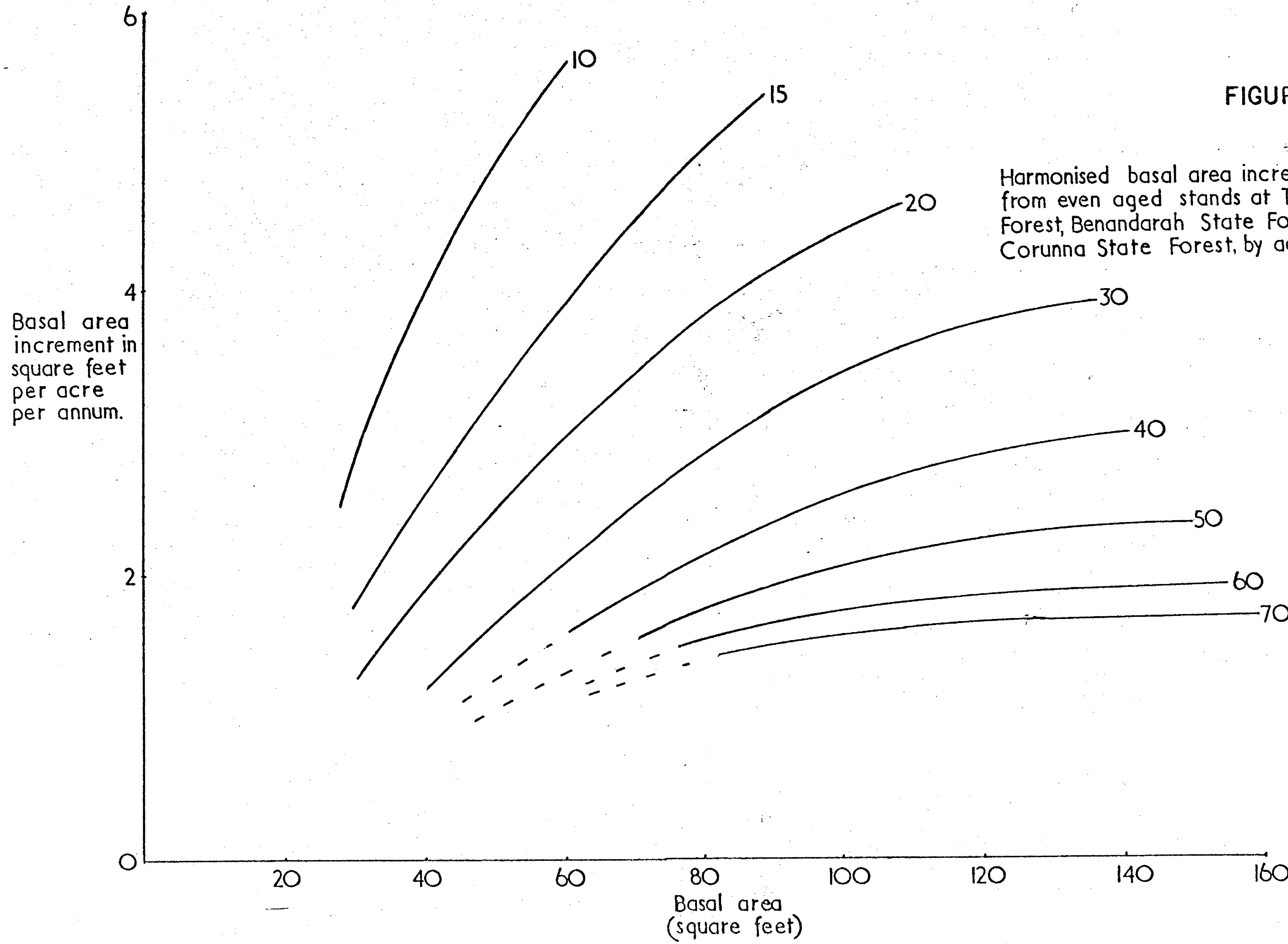
Curtin (1969a) describes in detail the construction of a yield table for even-aged blackbutt forests. The data was taken from 100 sample plots on the N.S.W. North Coast. Basal area increment decreases significantly with increasing age and stand density. A similar trend is shown by the spotted gum data and consequently it was decided to use Curtin's method in the production of a yield table.

The basal area increment data were graphed against basal area similar to Curtin's figure 1. These in turn are harmonised and redrawn to give figure 7, the backbone of the yield table. Curtin describes in detail the use of the graph (in figure 7) to obtain growth and production data.

Figure 7 allows projection of basal area at set ages from the increment data. In this way yield is divided into thinning and main crop. Volumes are calculated from mean diameter in a volume table. The number of trees can be adjusted to suit a desired structure.

FIGURE 7

Harmonised basal area increment data from even aged stands at Termiel State Forest, Benandarah State Forest, and Corunna State Forest, by age classes.



The basal area yield for the production of sawlogs and for the production of mining timber are set out in detail below (Tables 30 and 31). The stand chosen as a starting point is below the basal area and average diameter increment levels of the Benandarah Plantation which is probably better than average for the whole of the spotted gum forest. The increment rates used for the retained stand are drawn from the dominance 1 and 2 rates presented in Table 28. Volumes were calculated by the "Silres" equation after estimates for height were made from all stands involved and the trees felled to check the volume table.

TABLE 30 - Calculation of basal area and volume yield for sawlog production.

Age (yrs) BT (before thinning) AT (after thinning) TY (thinning yield)	Number of trees	Basal Area (sq.ft. per acre)	Diameter (inches) equiv.to mean basal area.	P.A.I. for basal area (sq.ft per ac. per an.	Merch-antable height estimate (feet)	Volume per tree su.ft per acre	Volume per Acre.
10	400	4.5	4.5	4.5	nil	nil	nil
25 BT	400	111.0	7.1	4.3			18280
25 AT) *	120	61.5	9.7		50	119	14280
)	120	10.4	4.0		Nil		Nil
25 TY	160	39.1	6.7		23	25	4000
40 BT	240	115.4	9.4	2.9			23000
40 AT) *	60	66.0	14.2		50	257	15420
)	50	6.8	5.0		4	Nil	Nil
40 TY) *	60	28.6	9.3		50	110	6600
)	70	14.0	6.1		17	14	980
60 BT	110	111.8	13.6	1.95			24540
60 AT	40	80.4	19.2		50	471	18840
60 TY) *	50	10.0	6.1		17	14	700
)	20	21.4	14.0		50	250	5000
80 FF (final felling)	40	115.4	23.0	1.75	50	675	27000

* Where marked the stand is comprised of two distinct parts, the parts are bracketed.

TABLE 31 - Calculation of basal area and volume yield for mining timber production.

Age (yrs) BT (before thinning) AT (after thinning) TY (thinning yield)	Number of trees	Basal Area (sq.ft. per ac.)	Diameter (inches) equivalent to mean basal area.	P.A.I. for Basal Area (sq.ft per ac. per an.)	Merchantable height estimate (feet)	Volume per tree (su.ft.)	Volume per Acre
10	400	4.5	4.5	4.5	Nil	Nil	Nil
20 BT	400	8.9	6.4	4.4			9980
20 AT)*	220	53.6	6.7		23	25	5500
)	100	8.7	4.0		Nil	Nil	Nil
20 TY	80	26.7	7.8		36	56	4480
40 FF)*	220	105.8	9.4	3.0	50	111	24420
)	100	16.5	5.5		10	4	400

Where marked * the stand is comprised of two distinct parts, the parts are bracketed.

This data allows the presentation of a formal yield table, Tables 32 and 33, for the spotted gum forest developed under even-aged stand conditions.

The initial stand at age 10 comprises 400 trees, 45 square feet basal area and mean diameter 4.5 inches. Spotted gum appears to be a tree slower to commence rapid growth than blackbutt. Groups of trees with average diameter of 4.5 inches at 10 years have been observed in routine treatment areas on Brooman State Forest.

The management proposed aims at high diameter growth in the retained stand. Early mining timber operation assists this whilst at the same time making a quick monetary return. With control based on basal area not numbers, only the minimum amount of material between the unsaleable limits of 12 to 16 inches d.b.h. would be produced.

TABLE 32 - Yield table for even-aged spotted gum forest for sawlog production (volume in super feet H. per acre)

	Main Crop				Thinning Yield				Total Production			
Age.	No.	Diam.	Basal Area	Vol.	No.	Diam.	Basal Area	Vol.	Basal Area	Vol.	PAI	MAI
10	400	4.5	4.5	Nil	Nil	-	-	-	45.0	Nil		
											730	
25	240*		71.9	14280	160	6.7	39.1	4000	111.0	18280		730
											582	
40	110*		72.8	15420	130*		42.6	7580	144.5	27000		675
											456	
60	40	19.2	80.4	18840	70*		31.4	5700	193	361200		602
											408	
80	40	23.0	115.4	27000						44280		554

Total thinning yield	17280	su.ft
Final felling yield	27000	su.ft
	44280	su.ft

* denotes yield table values where products have two distinct components. These were set out separately in Tables 30 and 31; the smaller part in each was retained due to it being too small to be sold. Later when making up part of the yield the identity of the two parts has been kept to give greater realism to the average diameters and volume estimates made.

Similarly the table for mining timber production is :

TABLE 33. - Yield table for even-aged spotted gum forest for mining timber production.

	Main Crop				Thinning Yield				Total Production			
Age.	No.	Diam.	Basal Area	Vol.	No.	Diam.	Basal Area	Vol.	Basal area	Vol.	PAI	MAI
10	400	4.5	4.5	Nil	Nil	-	-	-	45.0	Nil		
											499	
20	320*		62.3	5500	80	7.8	26.7	4480	89.0	9980		499
											965	
40	320*		122.3	24820	-	-	-	-	149.0	29300		733

The volume M.A.I. predicted in the yield table is higher than the increments commonly accepted for the irregular spotted gum forests. Figures such as 5 or 7 cubic feet have been quoted (Curtin 1970). These rates are for the generally degraded dry sclerophyll forest of poorer quality than the South Coast spotted gum forests.

The yield table data are intended to represent the higher quality part of the dry sclerophyll range and the wet sclerophyll sites. Approximately 20,000 acres of the Bateman's Bay to Termeil study area would be in this class.

The yield table is not intended to present maximum values. The P.A.I. for the unthinned and lightly thinned areas at Benandarah S.F. exceeded those proposed in the tables. The 70 year M.A.I. for total production for the Termeil thinned plot at 480 super feet per acre per annum is not greatly below the 550 to 600 super feet per acre per annum expected in the yield table for the 60 to 80 year period. Termeil S.F. is only moderate site quality forest and did not benefit from early thinnings.

CHAPTER 5.

SILVICULTURAL SYSTEMS AND METHODS.

The silvicultural system designates a planned programme for the whole life of the stand, a reproductive phase is critical to the programme as a whole. The forests of the study area, both treated and untreated, are encumbered by large numbers of unmerchantable trees and the provision of regeneration to return these stands to full productivity is essential.

Regeneration treatment in the past has been successful. The factors restricting and promoting regeneration are a complex interaction of species characteristics, the site and its vegetation. It is intended to discuss the achievements of previous silvicultural treatment in relation to its aim and success.

5.1. Review of past silvicultural treatment.

Both records by way of maps and the memory of people associated with the forests for long periods have allowed the various treatments to be re-located and assessed. The history of regeneration can be divided into four "eras" and a current period. These are the periods of ringbarking, group selection, advance growth salvage and the clearfelling. The fifth, treatment for recreation, has yet to assume any significance other than a current desire for naturalness in the landscape. The four will be discussed in turn, the fifth will be reviewed in Chapter 7.

5.1.1. Results from ringbarking treatment.

Ringbarking treatments commenced in the forests north from Bateman's Bay prior to the 1920s when the aim was to remove from the growing forest the large overmature useless trees and raise the quality of growing stock. Regeneration did occur and present day examples of second growth pole sized forest originated in this way. However, the treatment was not designed primarily to produce regeneration but to remove the useless old growth. The success or otherwise of a ringbarking treatment in producing regeneration depended primarily on site and growing stock. Selective logging plus the ringbarking of the culls provided adequate space for the establishment of regeneration, unless prevented by understorey competition. Unfortunately, the understorey dominated in the higher quality sites and today large lower slope and gully bottom areas are but partially stocked following ringbarking and selective logging.

In the ringbarking treatments of the 1930s and early 1940s more small trees were ringbarked which helped regeneration to establish on the weed-free sites. The regeneration has grown vigorously where the residual stocking of old growth was low but where the overstorey has dominated the regrowth, growth has been poor. The two acre plot established on Benandarah supports this view. The stand had 51 living trees, 6 stumps and 18 ringbarked trees per acre. Eighty three square feet basal area were removed in the ringbarking and logging but only 22 living trees below 16.0 inches in diameter are present. All 22 trees are in the sub-dominant or suppressed classes, most have poor, class three crowns.

Ringbarking treatment has been successful in stimulating regeneration on the harsher sites away from the wet sclerophyll. Under these conditions the dynamically balanced lignotuber pool recorded by Henry and Florence (1966) allows the long established but not degraded lignotuberous seedlings to surge away, creating the regrowth stand.

5.1.2. Group Selection.

Following the period of ringbarking treatment the requirement for regeneration became more widely appreciated. The group selection system was used in an attempt to achieve both improved quality in the retained stand and regeneration. Jacobs (1955) describes the development of the system in a stand. Regeneration occurred in gaps in the forest. These were created by the fall of veterans due to natural decay and fire or otherwise by selective logging.

The system is best applied to forests of high quality where the gap created during felling operations is surrounded by trees which are able to benefit from the release. In latter years the routine treatment by this method also aimed at the removal of the useless trees throughout the stand.

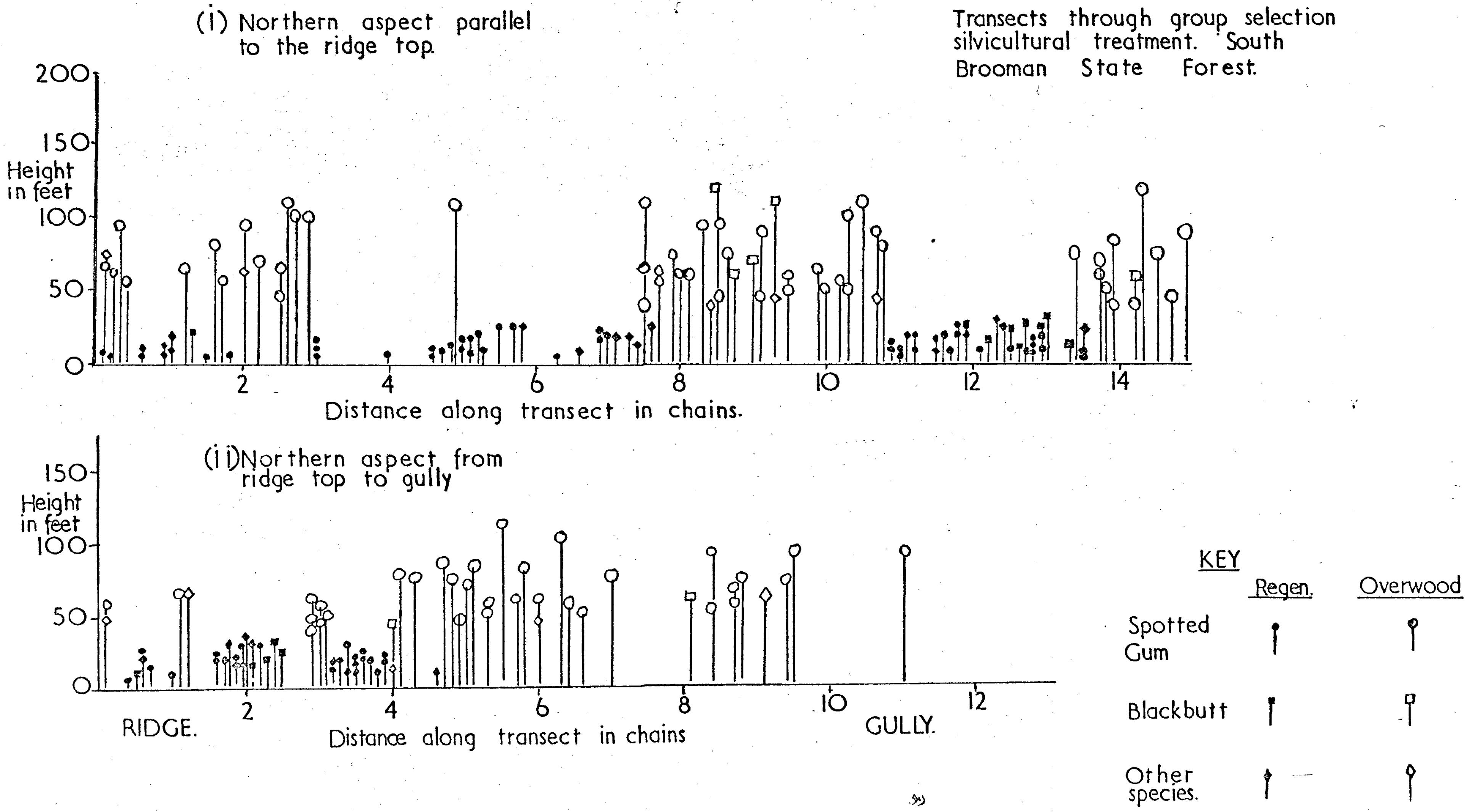
For irregular forest of high quality, such as occurred on North and South Brooman State Forests, the system worked well, producing regeneration in stands where the valuable advance growth required retention. To determine the success of the treatment randomly located transects were assessed. In each the overwood and regeneration were recorded. Strips were oriented either parallel to or across the contour.

The results were graphed by species and height both within the overwood and regeneration and diameters were measured for the overwood. Almost 8 miles of transect were used to sample the four systems. Regeneration was recorded for 4 feet each side of the transect line whilst the overwood was recorded for 33 feet each side. Considerable variation occurred within the strips in density of both regeneration and overstorey. I have selected what are considered to be average conditions and have presented these graphically.

Brooman forest has the oldest treatment and will be discussed as an example of the group selection system. The graphs in figure 8 show clearly the way regeneration occurs in the gaps created. The transects parallel to the contour were located approximately three chains away from

FIGURE 8

Transects through group selection silvicultural treatment. South Brooman State Forest.



the ridge top road and those across the contour were from road to gully.

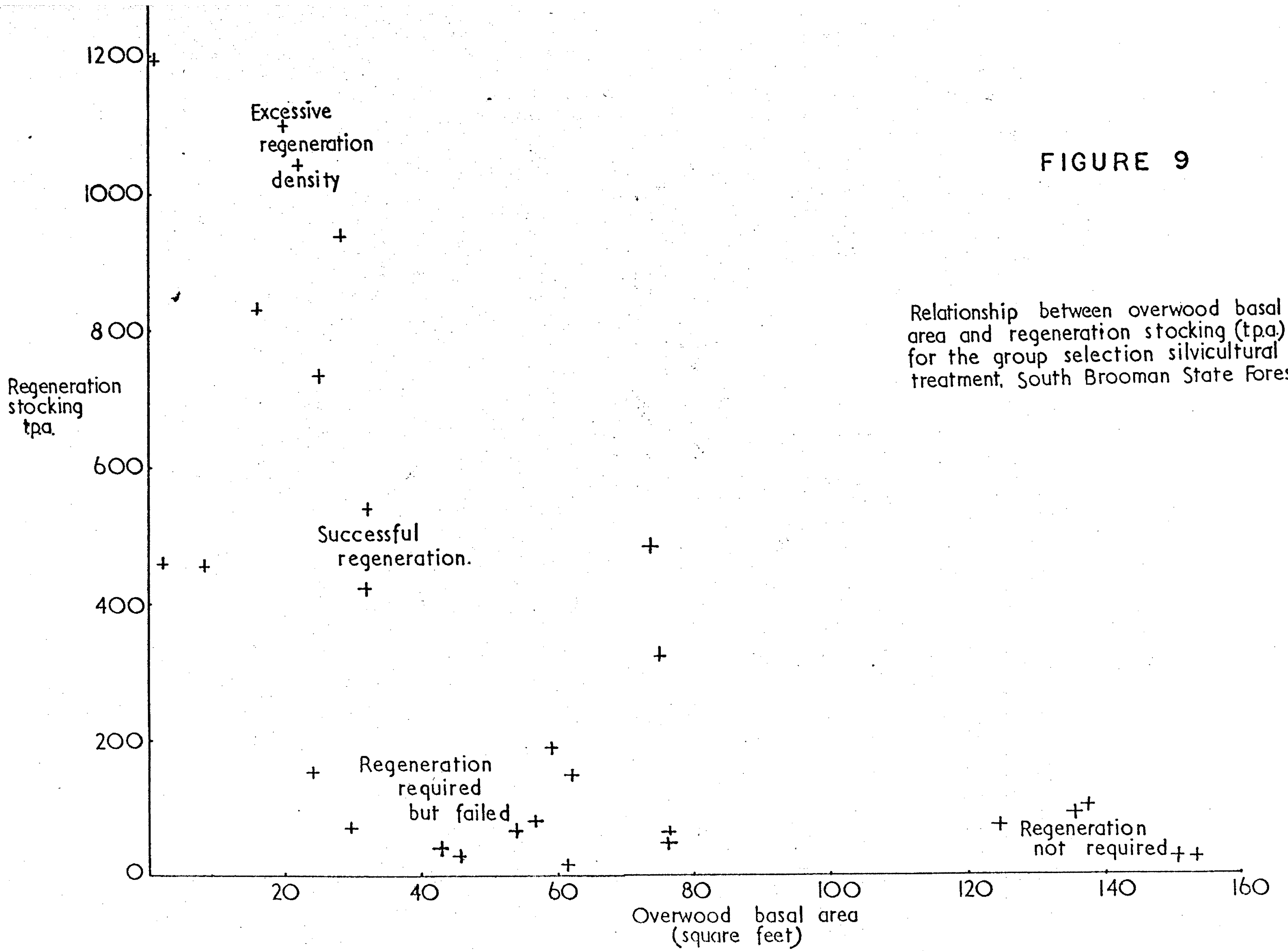
Regeneration stocking up to 1200 trees per acre occurred in the more open gaps. These regeneration openings were larger than recommended by Jacobs (1955) being up to 4 chains wide and 5 to 10 chains long. In between the gaps very little regeneration occurred due to the stocking density of the forest retained during the treatment. In places where regeneration occurred in small gaps created by removing individual cull trees the stocking is lower and height growth and crown vigour are poorer. The unrestricted regeneration has reached 40 feet in height 8 years after treatment. The graphs show clearly the edge effect around the group, the tallest regeneration is always in the opening with decreasing height to the edge of the gap. This competition factor is greater for small groups than for larger groups.

On both the northern and southern aspects sampled parallel to the ridge, good regeneration was found to occur in the openings. This point is made to counter past criticism of the system which arose when regeneration failed following cull treatment between the regeneration openings. Such openings were hedged around by moderate levels of overstorey and consequently should not have been expected to regenerate. The retained stand should occupy the remaining site with growing stock able to use the site fully. If insufficient good quality growing stock is available between the regeneration openings then it must be clearly recognised the group selection system is not applicable and the forest should be handled in some other way. The advance growth salvage or clear fell system is more likely to be applicable under these conditions.

The pattern of regeneration distribution in relation to overstorey is graphed in figure 9. The occurrence of satisfactory regeneration stocking at basal area densities less than 40 to 60 square feet is seen.

FIGURE 9

Relationship between overwood basal area and regeneration stocking (t.p.a.) for the group selection silvicultural treatment, South Brooman State Forest.



Some failures are evident.

Success in establishing regeneration within the openings was limited to the areas parallel to the ridge top. This zone on the Brooman forest would be 4 to 6 chains wide on the southern aspect and up to 10 chains wide on the northern aspect. It would fit into the wetter range of high site quality dry sclerophyll forest. Beneath this zone the wet sclerophyll forest occurs and no regeneration is obtained.

Failure to obtain regeneration on the wet sclerophyll sites is due to two major factors. The first is the rapid capture of the site by weeds and vines, and the second is that the stand character does not suit the group selection system. The rounded flat ridges provided excellent access, the timber closer to the ridge was more easily taken and the second growth started in the gaps. The trees from the gullies were more carefully selected, fewer were removed providing less opportunity for gaps created by logging. The current gully stand consequently contains more old growth and is suited to advance growth salvage rather than group selection. High quality, selectively logged and treated stands suitable for group selection are not particularly common.

The principal cause of failure to obtain regeneration irrespective of the silvicultural system used is the weed problem. This has been discussed many times by workers dealing with regeneration in wet sclerophyll Eucalypt forests of northern N.S.W. (Van Loon 1966, Holmes 1968). Many species of weed are common to both areas.

The occupation of the site by weeds was studied by Floyd (1965) who found rapid and prolific weed growth following slash burns in wet sclerophyll Eucalypts. Wattles and soldier vine were the greatest problem due to their woody nature, rapid growth and perennial habit. Soldier vine scrambles and pulls over the regenerating Eucalypt. Van Loon (1966) working in tallowwood forests near Taree emphasised the need for seed bed preparation. No regeneration occurred without it. Holmes (1968) attributes the failure of blackbutt to regenerate in moist sites to the heavy and intense weed and vine competition. The same pattern is observed for spotted gum.

In all instances the use of controlled fire could produce the required receptive seed bed but the risks involved are high, particularly if natural sources of seed are to be used in the re-stocking. Due to the rapid weed competition the burning has to be co-ordinated with seed shed or sowing. This has to be followed by good conditions for germination and growth.

To overcome the uncontrolled factors, site preparation by tractor has developed. Floyd (1965) measured eighteen times the weight of problem weeds on a series of burnt areas compared to the unburnt, tractor cleared sites. The difference in total weed growth after one year was 1.32 tons per acre for the burnt and .38 tons per acre for the tractor cleared and the latter comprised mainly "innocuous annuals". The slower onset of competition allows the regeneration to be undertaken at more convenient times for the labour force and in seasons with more reliable and suitable weather. If necessary it can be delayed or tied in with the time of natural seed shed, and as Van Loon (1966) pointed out, the seed trees left are not damaged and may therefore contribute to stocking over a number of years.

The technique of baring the soil by tractor to overcome the weed problem is now accepted practice on many North Coast forests. For the South Coast one experimental area of approximately 50 acres on Brooman State Forest was treated and this verified its suitability and effectiveness to cope with the weed problem of the spotted gum and spotted gum -

Heavily logged spotted gum forest before treatment.

Virtually all trees in the photograph are unsaleable.

South Brooman S.F.

Forest similar to that shown in the upper photograph after treatment by tractor. The soil surface was bared and the debris heaped.

South Brooman S.F.

blue gum wet sclerophyll forest types.

Holmes (1968) and Van Loon (1966) both discuss variations on the basic tractor clearing technique and no valid technical reason is known why similar variations should not be feasible in the Bateman's Bay area. One variation has become well known as the snig track extension method. It requires the 10 to 20 percent site disturbance from logging to be increased to 50 to 60 percent by the extension of the snig tracks. This is achieved by tractor pushing the maximum of bare soil with the minimum of work. A second variation involves the use of heavy tractors to create windrows spaced regularly or irregularly over the area where the heaped debris is restricted to 10 to 15 percent of the site giving virtually a full stocking right to the edge of the debris. Although more costly, later logging costs will be much reduced.

The dry sclerophyll forest without the weed problem in the regeneration stand also gains by use of the tractor for silvicultural treatment. Most of the argument in favour of tractor use still applies for, as is shown later in the Kioloa clearfell study, the disturbed soil will carry better regeneration. Fire weeds still occur in the dry sclerophyll and so the more flexible treatment not requiring controlled burning is useful in this instance as well as in wet sclerophyll. In the graphs in figures 10 and 11 the absence of regeneration where there is little overstorey is due to vine and weed domination of the site. The wild grapevine, Cissus spp, is the main offender. These weeds occur without fire and with fire other weeds add to the problem.

5.1.3. Advanced Growth Salvage.

The major factors affecting the choice of a silvicultural system are the growing stock quality and the level of utilization. The utilization standards on the South Coast are high and therefore the growing stock becomes the primary factor. Jacobs (1955) describes advance growth as "established seedlings saplings or poles which are present in a forest ....". The larger members such as saplings, poles and logs are more important in the context of this thesis.

The advanced growth salvage system is used to retain stand members which will grow at a satisfactory rate, particularly those near merchantability, at the same time removing undesirable trees which are useless or will render regeneration difficult.

For the east coast Eucalypt forest two broad applications for the method exist. They are firstly, for the high quality forest where adequate advance growth exists to utilize the full site productivity and the logging and treatment aims at the retention of quality growing stock to the prescribed stand density. Trees in excess of this limit will be removed by logging and treatment to give a vigorous stand without a regeneration requirement. This type of forest is quite rare, arising from previous treatment and well controlled logging. Benandarah State Forest has some areas of high quality irregular forest which approach this condition but more often forms a mixture with the second type.

The second application is widespread and has been applied to the major portion of all areas treated in the last decade. It retains the desirable advance growth but removes the less desirable trees replacing them with regeneration. What is retained varies greatly, from the full stocking discussed in the preceding paragraph, to nothing, that is clear-falling. The level of trees retained between these two extremes depends upon quality and the management objectives. At times in the past utilization was not as high as it is today and also the need for low overstorey competition as a prerequisite for good regeneration was not as widely recognised. The growing stock responded poorly and regeneration created or stimulated by the treatment was soon suppressed by competition.

Moderate success was achieved when the need to reduce competition was recognised and accompanied by heavier logging and treatment. In recent times the system has been very successful when used with complete logging of all saleable material and strict quality control of the smaller stand members. The trees retained rarely exceed 30 square feet basal area and regeneration numbers exceeding 1000 have been achieved. Natural dominance within the stand limits the effective trees to about 400 per acre, a desirable stocking. If the higher number persisted excessive density would be a difficult problem for the future.

Transects through this type of treatment are shown in figures 10 and 11, where the pattern of spaced trees without a grouped condition is evident. The relationship between stocking density and regeneration can be followed from the examples.

At stocking densities less than 40 square feet of overstorey basal area regeneration occurs in adequate numbers. Stand "locking" has been recorded by Curtin (1968) in dense regeneration. Techniques may be needed to overcome this on the South Coast. Possibly the use of well controlled ground fire could offer a method of encouraging segregation into dominance classes. However, at present natural dominance is well established and the stands are satisfactory.

Jacobs (1955) has viewed the advance growth salvage system as setting the stage for the future group selection system. This is no doubt true for certain situations but for others the system moves towards the even-aged condition. When strict quality control is exercised over the retained stand the forest can be made even aged at the end of one rotation The form of the system will be directed by management objectives and growing

FIGURE 10

Transects through forest, treated by the advance growth salvage silvicultural system on Boyne State Forest.

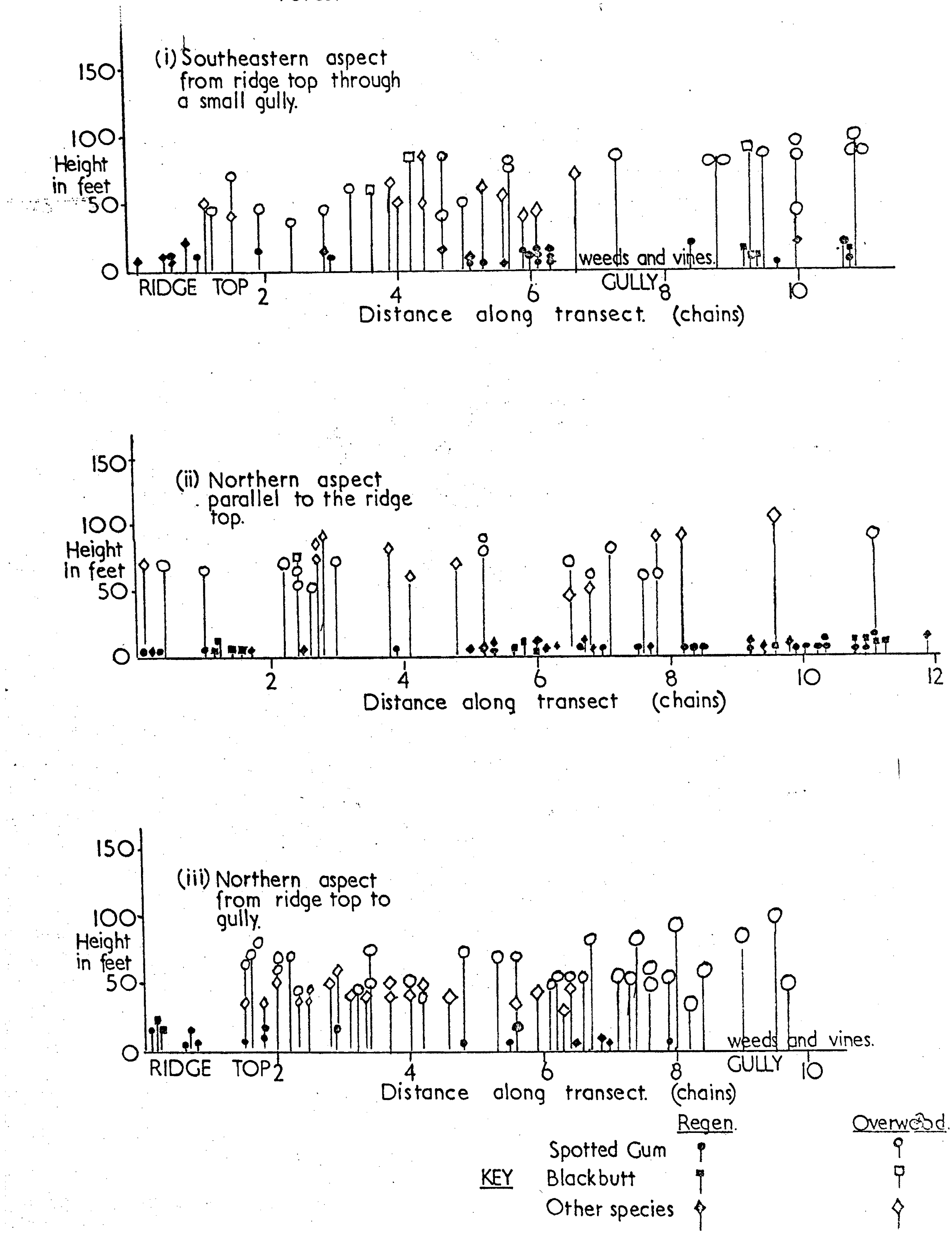
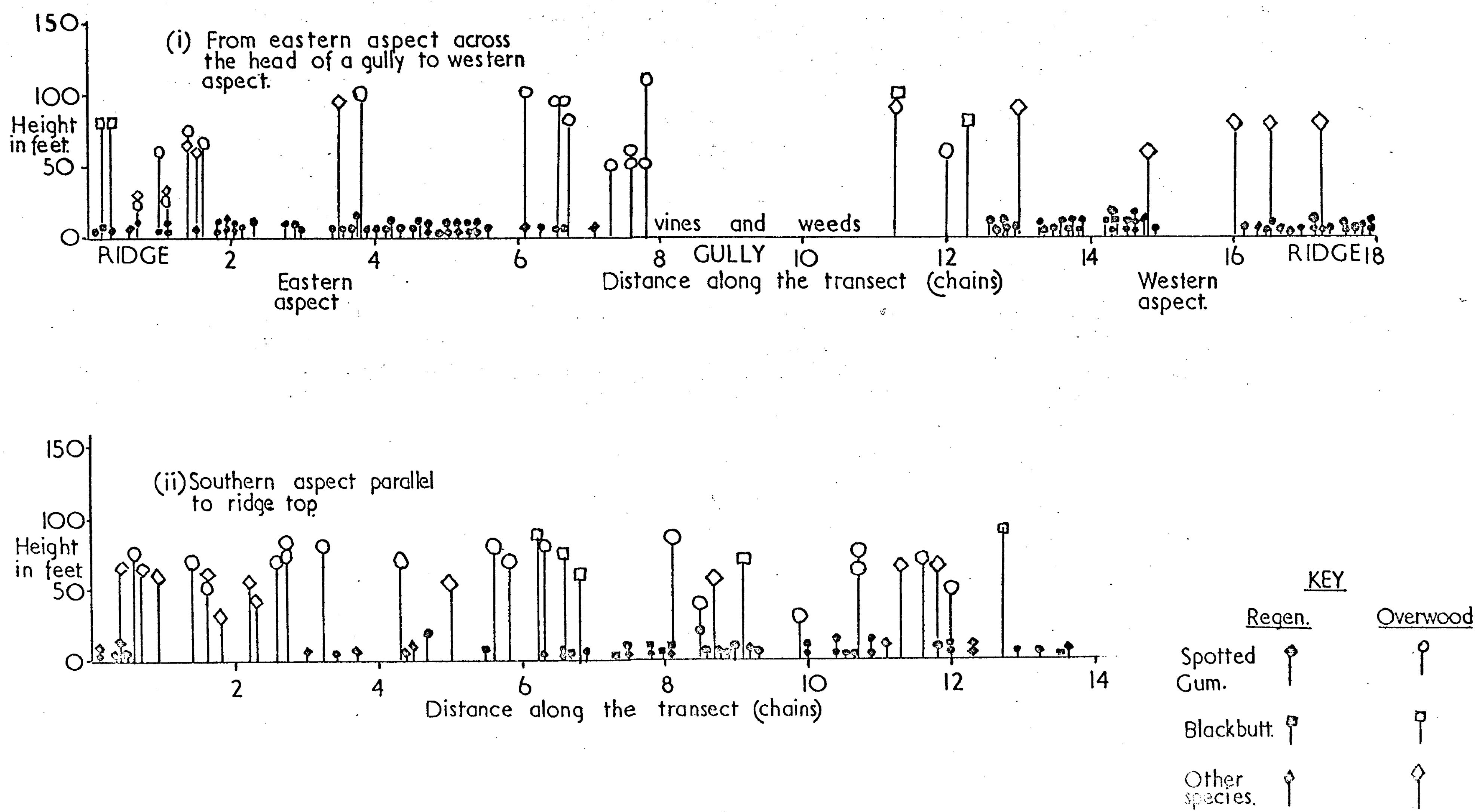


FIGURE II

Transects through forest treated by the advance growth salvage silvicultural system on Kioloa State Forest.



stock quality. The clear cutting with seed trees system is for convenience included within the advance growth salvage section. The trees retained should be good quality growing stock to ensure merchantable increment. It can be regarded therefore as salvage for a twofold purpose, provision of seed and retention of trees of good quality.

In this system, as well as the group selection system, the regeneration phase can fail entirely due to capture of the site by weeds and vines. The graph for Kioloa transect number 6 shows this feature excellently, the absence of regeneration in the middle of the strip corresponds exactly with the commencement and cessation of dense cissus vine and shrubs across the head of a gully. The striking success of the Boyne forest transect is a fine example of dry sclerophyll forest of moderate site quality. Lignotuberous seedlings contribute substantially to restocking in this area.

5.1.4. Clearfall.

The clearfall is used to convert highly defective stands quickly into productive forest. It has a number of management advantages over the selection forest but in the regeneration stage is not attractive for recreation.

Clearfelling is best suited to the overmature forest that has not received the benefit of previous ringbarking or other silvicultural treatment. An area of 20 acres was clearfelled as an experiment in 1967 and a larger area was treated by this method in 1968. A study was established in the 1967 block to observe the regeneration stocking obtained. A second study in the 1968 block investigated the effect of drought and burning on the results of the method.

The smaller area, known as the Joes Nose Road area, is in Boyne State Forest on dry sclerophyll spotted gum - ironbark type.

It is a side ridge off from the main ridge. Transects were arranged to sample all aspects ranging from 30° to 220°. The regrowth was recorded along the transect by species, spotted gum or other species, principally ironbark, and by height. Coppice growth was recorded in the same way. Height differences were not great nor formed any pattern. After two years the dominant regeneration had reached 10 to 12 feet. Spotted gum regeneration from seed or lignotuber had a stocking of the order of 100 per acre whilst the other species stocking approached 150 per acre, coppice in each group was approximately 50 per acre - Table 34.

TABLE 34 - Stocking on Clearfelled area - Boyne State Forest.

Transect Reference Number.	Length of Transect (8 ft.wide) chains.	Aspect Bearing in degrees	Stocking per Acre.				
			Spotted Gum		Other Species		Total
			Regeneration	Coppice	Regeneration	Coppice	Allform
1	7.5	30	77	55	110	66	308
2	12.0	70	110	41	256	48	455
3	14.0	110	136	35	218	30	419
4	10.2	150	137	89	65	40	331
5	8.7	190	48	38	162	28	276
6	5.7	220	103	29	115	72	319

With an effective stocking of from approximately 300 to 400 trees per acre the Joes Nose Road area is considered to be successfully regenerated and returned to productivity.

Unfortunately the same cannot be said for the second and larger area. It is located on Kioloa State Forest and is known as the Ryans Creek area. The felling was made during the period of extreme dryness in 1967 and 1968. Following the severe fire season in 1968 great fear was expressed of the potential disaster likely if the clear-felled area was burnt during bad times. A study was subsequently established to observe the effect of slash disposal burning by mild autumn fire. The 150 acre block was subdivided into 8 and subsequently 4 sub blocks were burnt in Autumn 1969. The stocking of the area was assessed after 3 months and 9 months. After three months the following per acre stocking was recorded :-

from the burnt area, 61 seedling regeneration and 1 lignotuber;

and for the unburnt area, 100 seedling regeneration and nil lignotuber. Overall for the 40 chains of transect little difference was observed between the nominally burnt and unburnt, both were poorly stocked. However, for the burnt blocks the regeneration mostly occurred on the disturbed ground of the snig tracks which was not burnt in the fire.

The second assessment at 9 months looked more closely at this factor of site disturbance. The details are given in Table 35.

TABLE 35 - Stocking on clearfelled area Ryans Creek - Kioloa State Forest.

Length of Transect (chains)	Stocking per Acre			
	Nominally burnt block		Unburnt block	
	Unburnt areas associated with disturbed sites	Burnt areas both disturbed and undisturbed sites	Disturbed site	Undisturbed site
84	95 seedlings 5 lignotubers	12 seedlings 10 lignotubers		
70			55 seedlings 11 lignotubers	21 seedlings 24 lignotuber

The disturbed sites occupy at a maximum 15 to 20 percent of the acre but carry proportionately far more regeneration on both the unburnt and burnt blocks. For undisturbed sites on burnt areas, 22 new stems per acre are far too low and the site is now claimed by fire weeds of <u>Kennedya spp</u> and wattle thus preventing artificial seeding.

Burning to reduce the fire hazard removes established regrowth and prevents new natural germination by destroying the seed in the crowns and capsules on the ground. If burning is necessary the treatment should be co-ordinated with artificial sowing either by hand for small areas or preferably by aerial distribution for larger areas as described by Grose, Moulds and Douglas (1964).

The Ryans Creek clearfell was continued during the wet year of 1969, after the drought had broken. In this latter area stocking rates up to 2000 seedlings per acre, virtually all from seedling origin, have bean recorded. The 1968 and 1969 areas are similar in forest type and understorey vegetation indicating the difference in regeneration, from deficiency to excess, is due to the seed source and climate for regeneration. Treatment by the clearfelling method was restricted to the spotted gum types which had a dry sclerophyll character. The weed and vine problem discussed in the other systems for wet sclerophyll forest would also doom the clearfell treatment to failure.

5.1.5. Origin of the regeneration.

In all the silvicultural systems discussed above regeneration could have been achieved by natural seeding, artificial sowing or jiffy pot planting. All can be extremely successful in particular situations. The most expensive treatment is jiffy pot planting, but this technique is very reliable. From the author's own experience artificial seeding methods from spot sowing to broadcast sowing by hand and aerial methods have all given successful results but considerable variation in stocking can occur through vagaries of the weather and site. This variation is undesirable for management and yield forecasting so therefore the assured stocking at a defined number per acre obtained with jiffy pot planting has great value.

5.1.6 Discussion.

The four silvicultural systems, ringbarking culls, group selection, advance growth salvage and clearfelling, have all proved successful in dry sclerophyll forest. Extreme drought reduces the efficiency of all four systems. In wet sclerophyll forest the four systems have all failed due to rapid colonisation of the site by weeds, vines, wattles and dense shrubs. These wet sclerophyll areas are the higher quality sites, often with a rain forest understorey of shrubs and vines present before logging and treatment. They have no advance growth such as lignotubers. The rainforest understorey consistently indicated an absence of lignotubers in all studies.

The data presented gives good reason for separation of the wet and dry sclerophyll forest into two distinct entities for silvicultural treatment even though this will mean some logging units will be divided, lower slopes to the wet sclerophyll and upper slopes to the dry.

For the wet sclerophyll site, the risk involved in any treatment including burning is considered too high. Weather patterns for Southern N.S.W. are more severe and more variable than in Northern N.S.W. Therefore, no logging should be undertaken where regeneration is required unless some form of site preparation by tractor clearing is to follow. Where heavy logging is carried out without tractor treatment virtual abandonment of the site for both timber production and recreation will be the consequence and must be accepted at the time the decision to log is made.

The use of the tractor to provide a system of heaps and bays, not necessarily in regular pattern, will facilitate the use of mechanised harvesting for thinning. The thinning is critical for balanced stand development and health. To prevent thinning by broadcast felling or tractor clearing methods defeats the purpose of the regeneration which is to provide mining timber as well as sawlogs at a low cost. Hanson (1965) presents details and costs for pine plantations to support the need to manage the forest with silvicultural systems which help rather than hinder in the economic development. The same must be done for hardwood where the problem is much greater. If harvesting is ignored as it is with the broadcast clearfell, the result is more likely to be total loss of the thinning crop and subsequent set back to the main yield. If tractor clearing and heaping is done, the advantage to be gained by planting the desired number of trees by the jiffy pot technique is desirable. Sowing, although somewhat cheaper, may through the uncontrolled weather pattern cause excessive or deficient numbers at irregular spacing which will either reduce productivity or create extra costs in non-commercial thinning.

For the dry sclerophyll forest continued treatment using the lignotuber pool with or without enrichment planting following simple site preparation is likely to give continued success. The lower site quality also has less debris and the problem of futre access for thinning is likely to be less severe. Ideally, treatment of the dry sclerophyll type would be carried out by tractor on similar lines to the wet sclerophyll If hand or chain saw treatment is continued the treatment of the dry sclerophyll will be more rewarding than treatment of the wet sclerophyll. These recommendations for site preparation apply to all systems.

In areas where recreation values are high the opportunity is given by the use of the tractor to prepare a satisfactory site for small groups of reproduction or planting. Planting allows rapid re-stocking and thereby increases the value of the forest by reducing the regeneration period. Costs for the various treatments are difficult to obtain and to compare due to the risks involved.

Holmes (1968) reports tractor clearing to be cheaper than chain saw clearing without costing improvements in weed control and seed bed preparation. This situation was found to exist in Bateman's Bay. Hand work costing between $16 to $18 per acre was replaced by a tractor performing a similar task, i.e., broadcast felling. The tractor cost was $10 to $12 per acre. A trial area was windrowed and soil bared as a seed bed. The cost was $15 to $16 per acre.

The money cost is only part of the comparison. In the future labour will become more expensive and physically hard and unpleasant manual tasks such as chain saw work on debris strewn sites will not be acceptable. It is likely manual output per man day will decline, but skilled operators on technically advanced machines should produce an increase in productivity. Fortunately the trend to mechanisation is a desirable one for silvicultural treatment.

A similar philosophy prevails with the difference between sowing and planting. The $10.00 to $15.00 increase in total cost of planting in preference to sowing is considered justified by the assured stocking and defined spacing.

In summary, hand treatment with chain saws should be restricted to dry sclerophyll sites where no weed problem exists and regrowth will come largely from naturally shed seed and the spotted gum lignotubers. Logging to an intensity requiring regeneration treatment should only be considered for the wet sclerophyll forest when subsequent treatment will include tractor clearing to form a bared seed bed.

Planting assures a desirable stocking density, sowing or natural seeding does not.

The decision to use group selection, advance growth salvage or clearfelling depends on the quality and distribution of the growing stock combined with the objects of management. Group selection requires a grouped condition of good quality growing stock due to past logging and treatment history. Multiple use or recreation objectives place more importance on the appearance of the stand than growth rates and productivity.

Selection felling has certain administrative disadvantages.

These include; reduced volume for the total area logged, and mining thinnings which are unattractive in scattered stands. Unless highly qualified personnel is used for tree marking, selection felling often results in felling the dominant and co-dominant trees using a girth limit. This produces lower growth in the retained suppressed and poorer crowned individuals. Damage to the retained stand members occurs at logging. Additionally, the area is constantly fire prone, for following each treatment cycle irregular areas are regenerated. Little opportunity exists for hazard reduction without damage to the regeneration.

Management of the even-age condition has advantages which include simplified supervision for logging and fire protection. These were recognised by Florence (1969a) who also warned of the ecological problems associated with conversion of fragmentary mosaic forest to even-aged condition. The South Coast situation can overcome this problem by integration of both blackbutt and spotted gum even-aged areas depending upon the original distribution pattern as both are equally acceptable as mining timber.

5.2. Silvicultural Systems designed to improve the increment and yield from Irregular Forest.

The effect of different silvicultural treatment on the standing forest forms the second part of this chapter on silvicultural systems. Both aspects, regeneration and increment on the established forest, are integral parts of the continuing forest. The features of major importance for growth are the quantity and quality of the growing stock. In the forests examined large proportions of the standing volume were unmerchantable.

The high proportion of useless material is not confined to the spotted gum forest, it occurs in other Eucalypt species associations on the South Coast as well as in other parts of Australia. Henry (1960) described a spotted gum - ironbark stand in Queensland, where useless stems account for almost half the standing basal area, and effective increment was only one third of the total. Florence (1970) quotes Curtin who examined five managed forests on the east coast of N.S.W. and reported the useless volume ranged from 35 to 49 percent of the total which is in accord with the data for South Coast spotted gum. Curtin (1970) describes the failure of extensive treatment over the past forty years to keep pace with exploitation. He suggests treatment for stand improvement will be required continually to remove the useless material.

In an area of mixed hardwood forest near Coffs Harbour, where silvicultural treatment had produced a vigorous irregular forest, Jacobs (1954) examined stocking numbers. He proposed two levels of stocking and below they are compared with Benandarah data. The upper line of stocking figures is for a forest of less tolerant species where 1 to 2 chain openings occur during exploitation, the lower line represents a more tolerant forest with heavier stocking and where the regeneration openings are smaller.

i) Jacobs

	Diameter Class at Breast Height in Inches				
	5.7 to 11.5	11.5 to 17.2	17.2 to 22.9	22.9+	Total
Less tolerant stand (t.p.a.)	30	15	8	4	57
More tolerant stand (t.p.a.)	32	25	10	6	73

ii) Benandarah

	Diameter Class at Breast Height in Inches				
	4 to 12	12 to 20	20 to 24	24+	Total
Stocking (t.p.a.)	52	21	9	8	90

Curtin (1963), using data for a high quality irregular blackbutt forest, produced an ideal stocking distribution capable of high volume growth. This stocking in four inch diameter classes compared with Benandarah data is -

Diam. class in inches	4-8	8-12	12-16	16-20	20-24	24-28	28-32	32-36	36+	Total
Blackbutt stocking(tpa)	23.8	16.2	11.0	7.5	5.1	3.5	2.5	1.6	1.1	72.0
Benandarah stocking(tpa)	30.	22	11	9.6	8.6	3.8	3.2	0.6	0.3	89.1

Stocking numbers for Benandarah are similar but somewhat higher.

Henry (1960) working in coastal hardwood forests of south eastern Queensland reported a series of silvicultural treatments designed to improve the useful growth of a spotted gum - ironbark forest on soils of low fertility. The area had been intensively logged but not treated and advance growth was present. The treatments were based on various degrees and methods of removal of the useless residual stand and spacing out trees in the useful part of the stand for better growth. The control area received no treatments, a second area had minimum treatment by removal of useless material only and in the third and fourth treatments as well as removing unmerchantable material trees were coppiced for regeneration where form was poor. Selected trees to be left were spaced according to a schedule based on top height. All treatments (other than control) responded by increased diameter increment, but all including the control had similar basal area increment. The proportion of useful basal area increment was greater in the three areas treated. The annual merchantable volume increment was 87 super feet per acre per annum for the control plot and ranged from 133 to 139 super feet per acre per annum for the treated plots.

Working in the spotted gum forests of south eastern Queensland, Florence, Shea and Pegg (1970) examined the Queensland Forest Service silvicultural prescription and the average forest condition over which it applied and compared this with an alternative schedule. The routine logging schedule included the application of a strict cutting girth limit, whilst in silvicultural treatment retention of all trees with a minimum future product was prescribed. When the intermediate and suppressed trees were released by removal of the dominants the suppressed secondary stand members become the major part of forest capital. These do not respond vigorously but instead, degrade the stand and restrict the development of smaller advance growth and regeneration. The study was directed to changes in the logging schedule and treatment options. The alternative schedule discarded the cutting girth limit in logging, and removed the poorer formed least vigorous members of the stand in treatment.

Two areas of irregular blackbutt forest on Pine Creek were treated by the Australian Forestry School and later re-treated by the Department of Forestry at the A.N.U. Florence (1969) reported the details of the treatment and subsequent growth. The forest has a wide range of size classes. Advance growth salvage treatment retains and fosters the smaller material,both young and old, created or released by the earlier logging. Florence suggests division of this material into slow growing trees under undisturbed canopy and and trees arising from lignotubers or seedlings in the gaps caused by management.

The two treated areas are the 1949 treatment and the 1955 treatment. The former was logged heavily in 1949 following a fire in 1944, damaged and useless trees were felled, pole sized trees were thinned and groups of regeneration released. The 1955 treatment was more conservative than the 1945 treatment retaining as much growing stock as possible. Following logging only the completely useless were felled or ringbarked. The following growth rates and stocking were recorded :

	1949 area	1955 area
Diameter increment		
(i) Blackbutt (inches)	0.60	0.30
(ii) Other Species (inches)	0.39	0.18
Basal Area increment (square feet)	3.2	3.1
Volume increment (cubic feet)	99	72

Florence considered the increment rates of the 1949 area were satisfactory but the 1955 area were restricted by poor crown conditions. True per acre impressions are difficult from diameter increment figures. Increments based on diameter are important in determining the size of trees in a number - size inter-relationship, particularly for economic forecasting, but for production comparison basal area increment is the more informative.

In the light of the results obtained and described above a series of experimental schedules were applied to the three sub plots of the nine acre area on Kioloa State Forest.

5.2.1. Application of Experimental Logging and treatment schedules to Kioloa State Forest.

The nine acre block on Kioloa S.F. is described in Chapter 3. The crown condition of many trees is poor, and the stand has a large volume of unmerchantable trees. The condition has arisen from a natural decline of the upper stand members as the spotted gum type does not regenerate to an even-aged stand without disturbance by man.

The high density over-mature stand was chosen for the study to guide future management in these and treated forests of lesser density of similar origins.

The nine acre block was divided into three plots each approximately three acres in size. One schedule was applied to each plot although in consideration of current yield the whole 9 acre block had each schedule applied in turn.

The three logging schedules are -

1. Clearfelling. All useful material was harvested including sawlogs and mining timber. Poles were infrequent and did not allow commercial removal, so were sold as mining timber.

2. Quality Stem Retention (Q.S.R.) All trees are removed except those with vigorous crowns and straight defect free bole; bole length minima are set in relation to tree diameter. These are :-

(i) for trees greater than 28 inches d.b.h. a 30 foot log length,
(ii) for trees 20 to 28 inches d.b.h. a 35 foot log length,
(iii) for less than 20 inches d.b.h. a 40 foot log.

Smaller diameter trees need to be judged capable of at least 40 ft bole length in the future.

3. Maximum Retention of Merchantable Growing Stock (M.R.M.G.S.)

A schedule designed to maintain the greatest level possible in usable growing stock after the application of a cutting girth limit. The chosen cutting girth limit was 28 inches d.b.h. All trees above 28 inches were felled as well as trees below 28 inches whose condition indicated the tree would be unlikely to survive a further twenty years. This was indicated by crowns where dieback and distortion showed clearly.

The yield to be obtained from the 9 acre block by application of the three experimental schedules is summarised in Table 36.

TABLE 36. Summary of Yield from application of the three experimental schedules to the whole 9 acre block. On a per acre basis.

	Clear Fell			Quality Stem Retention			Maximum Retention of Merchantable Growing Stock		
	No. (t.p.a.)	Basal Area (sq.ft)	Volume (super feet)	No. (t.p.a.)	Basal Area (sq.ft.)	Volume	No. (t.p.a)	Basal Area (sq.ft)	Volume (super feet)
Yield Removed	39.2	102.2	13727	31.1	82.5	10286	20.2	67.2	9160
Useful Volume Retained	Nil	Nil	Nil	8.2	19.7	3442	18.9	35.0	4566
Total	39.2	102.2	13727	39.3	102.2	13728	39.1	102.2	13726

Total bole volume is 42,995 super feet. The large volume of debris is evident when the bole volume is compared with the 13727 super fee of merchantable volume. The unmerchantable basal area to be removed by silvicultural treatment irrespective of logging schedule was :

	Number	Basal Area
Useless trees greater than 28" d.b.h.	4.5	53.0
Useless trees less than 28" d.b.h.	41.7	37.4
Total	46.2	90.4

The clear felled area produced the maximum yield, 13,727 super feet. The complete area is available for regeneration and treatment.

The application of the quality stem retention schedule yielded more volume than the maximum retention schedule. The volume difference was not great (1126 super feet per acre) although 31.1 trees per acre were removed in Q.S.R. compared with 20.2 in M.R.M.G.S. The maximum retentior scheme with the incorporated cutting girth limit retained more small trees and cut more large trees.

In retaining 18.9 trees and 35 square feet per acre basal area the maximum retention schedule produces a forest of different character to one with more stringent selection. This is particularly noticeable where removal of the dominants has occurred without creating large gaps in the forest. Under these circumstances the trees remaining appear widely thinned and free to grow, whilst at the same time still fully occupying the site. It creates a forest where the vegetation character has been disturbed but not destroyed. This form of treatment and approach is more acceptable to naturalists and open to less criticism. In areas of high recreation value the removal of unmerchantable material may require a series of silvicultural treatments.

The quality stem selection system alters the character of the forest. The example at Kioloa could be described best as clear felling with the retention of standards. Each individual tree stands starkly on its own.

All logging schedules show the forest is strongly dominated by unmerchantable material. If silvicultural treatment follows the stands all exhibit the effect of drastic treatment. The maximum retention schedule retains most of the old forest character but the growing stock remaining is of lower quality than in the quality stem selection treatment.

Following this assessment of the whole of the nine acres for each of the three schedules, one three acre plot was logged according to each schedule.

The stocking and increment detail for the two year period, 1969 to 1971, following logging and treatment of the useless material for the two plots not clearfelled forms Table 37.

TABLE 37. Increment and stocking of residual forest following logging under the quality retention and maximum retention schedules and subsequent removal of the useless trees.

	Quality Stem Selection						Maximum Retention of Merchantable Growing Stock					
Size Class (inches)	Less than 12	12-16	16-20	20-28	28+	Total	Less than 12	12-16	16-20	20-28	28+	Total
i) Growing Stock of the Retained Stand at 1969.												
Number(t.p.a)	1.3	1.3	2.8	4.1	.6	10.1	4.3	7.1	6.4	5.4	-	23.2
Basal area (square ft.)	.5	1.5	5.0	12.3	3.2	22.5	1.6	8.1	11.7	15.1	-	36.5
Volume (super ft.)	76	216	909	2560	720	4481	158	778	1455	2170	-	4561
Bole volume (1971) (super ft.)						6263						8880
ii) Increment on the retained stand for period 1969 to 1971												
Basal area (square feet per acre per annum).	0.05	0.05	0.2	0.35	0.05	0.7	0.15	0.25	0.45	0.45	-	1.3
Volume (super feet per acre per annum)	6	10	38	80	15	149	15	33	54	60	-	162

Average diameter increment is .31 inches per annum. The individual tree range is wide being from 0.10 inches per annum to 0.78 inches per annum for the quality stem schedule and 0.06 inches per annum to 0.60 inches per annum for the maximum retention schedule. The 1969 mean diameters are 20.22 and 16.97 respectively.

The low basal area increments probably reflect the normal limits to diameter increment. In a short time the regeneration stand will utilize the spare basal area productivity.

The similarity of volume increment in view of the difference in basal area indicates the better log quality of the trees retained in the Q.R.S. plot.

5.3 Discussion on Silviculture.

For areas without past treatment a large proportion of total volume is not merchantable. Silvicultural treatment to return the area to productivity is drastic and alters the character of the forest, producing even-age stands with or without salvaged advanced growth. This type of silvicultural treatment is not desirable for areas of high recreational importance where some less efficient treatment in stages would be required.

In areas which have received treatment in the past the merchantable proportion of the stand is larger, often occurring in a grouped arrangement, and the group selection system could be followed. This is a desirable system for recreational use, allowing continued logging, regeneration and cull removal treatment without major disruption to the character of the forest as a whole.

In any system where the overstorey was reduced to less than

40 square feet basal area regeneration was found in adequate numbers providing seed source, climate and seed bed were satisfactory. The dry sclerophyll forest is often able to produce the required conditions whilst weed competition prevents it in the wet sclerophyll. Seed bed preparation by tractor is required for the wet sclerophyll forest as the risks involved with burning and the burnt seed bed are too high.

CHAPTER 6

ECONOMIC ANALYSES OF TIMBER PRODUCTION FORESTRY.

6.0. General.

The details presented in the earlier chapters on growing stock and growth, are used to provide financial information to aid decision making. The restricted sources of the data are recognised, and consequently the analyses made have carefully guarded against representing a specific locality or quality.

Use will be made of the Faustmann equation in the analyses. In a comparison of five basic theories of investment Watt (1967) concluded the Faustmann formula, with certain restrictions and limitations was the only one which had an adequate basis in economic theory. Emphasis is placed on the moist dry sclerophyll and wet sclerophyll sites of higher quality for in these the problem of rehabilitation is greatest.

Financial comparisons are made for the management alternatives available in two forest situations. In the first, clear felling and planting to produce an even-aged forest is examined: (i) with management on an 80 year rotation for sawlog and mining timber production,

(ii) with the object of producing mining timber only on a 40 year rotation.

This form of comparison is valid for old growth, heavily logged forest where there is no alternative to broad scale regeneration if the site is to return to timber productivity, (Section 6.1)

In the second group, (Section 6.2), forest in good condition through restricted logging and treatment is considered for :

(i) continued production using the group selection system,

(ii) and (iii) clearfelling and planting for sawlogs and mining timber or mining timber only.

Rotation age for the two clear felling schemes is mainly determined by growth rates rather than financial factors. Product size and market requirements prevent significant reduction in size of either mining timber or sawlogs.

Tractor clearing and jiffy pot planting form the basis for cost analysis. Unfortunately insufficient cost, growth and yield data exist for a similar comparison using minimal treatment in the lower productivity dry sclerophyll types.

Mention has already been made of the successful windrow, clearing and jiffy pot planting trial made on Brooman State Forest. It was, however, too small to take the cost data as representive or average as the tractor cost was low and the plants and planting costs were high. Therefore costs were adopted from routine operations in moist blackbutt treatment as reported by Holmes (1968). These apply to the Taree district of the N.S.W. coast but no valid reason is seen to prevent similar costs being applicable to the South Coast; a slight reduction in clearing cost was made due to the smaller average diameter of trees on the South Coast forests.

The costs per acre are :-

Tractor clear and random heap or windrow	\$21.00
Plants, transporting and planting	\$24.00
Sub total	\$45.00
Overhead at 50 percent	\$22.50
Total	\$67.50
Fire protection and general maintenance occurring as an annual charge, including appropriate overheads	\$ 0.50

No land purchase cost is involved or proposed, as away from foreshores and rivers derelict land after intense logging would have a low value.

This low value however is not the reason for its omission as all land involved in the suggested treatment is currently State Forest and no purchase is necessary. Road construction and survey costs were provided by the previous crop.

Stumpage prices when reviewed over the past 30 years have risen from a basic one shilling per hundred nett to approximately \$2.30 per hundred super feet nett, for the same quality and size. The better than 20 fold increase was in part due to the original unrealistic stumpages left over from the days of development, when timber cover was a burden not an asset. The other part is due to inflation.

Estimation of the inflationary trend can not be made accurately and for this reason current values are used to calculate financial yields. However, it is recognised that inflation is a very real factor aiding the long term financial enterprise.

The stumpage rates used are :-

i)	for mining timber	\$1.00	per	hundred	super	feet.
ii)	for sawlog thinnings	\$1.40	"	"	"	"
iii)	for sawlog final felling	\$1.92	"	"	"	"

6.1 Economic analysis of production following logging and clear felling treatment.

If clear felling treatment is used to return the degraded selectively logged forest to productivity, the anticipated yield should be that prescribed by the yield table.

In Table 38 a summary is made of the volume produced and the value of the product.

TABLE 38 - Volume and value production data.

Age (yrs)	Volume per acre (super feet)	Stumpage per hundred super feet gross volume	Total Value	Product
i) for Sawlogs				
25	4000	$1.00	$40.00	Mining Timber
40	7580	$1.00	$75.80	Mining Timber
60	700	$1.00	$ 7.00	Mining Timber
60	5000	$1.40	$70.00	Sawlog thinning
80	27000	$1.94	$523.80	Saw logs
ii) for Mining Timber				
20	4480	$1.00	$44.80	Mining Timber
40	24820	$1.00	$248.20	Mining Timber

With these data and using the Faustmann formula in the re-arranged form presented by Lugton (1968), discount tables allowed the calculation of financial yield (Table 39). In Figure 12 soil expectation values were plotted against rate of interest used.

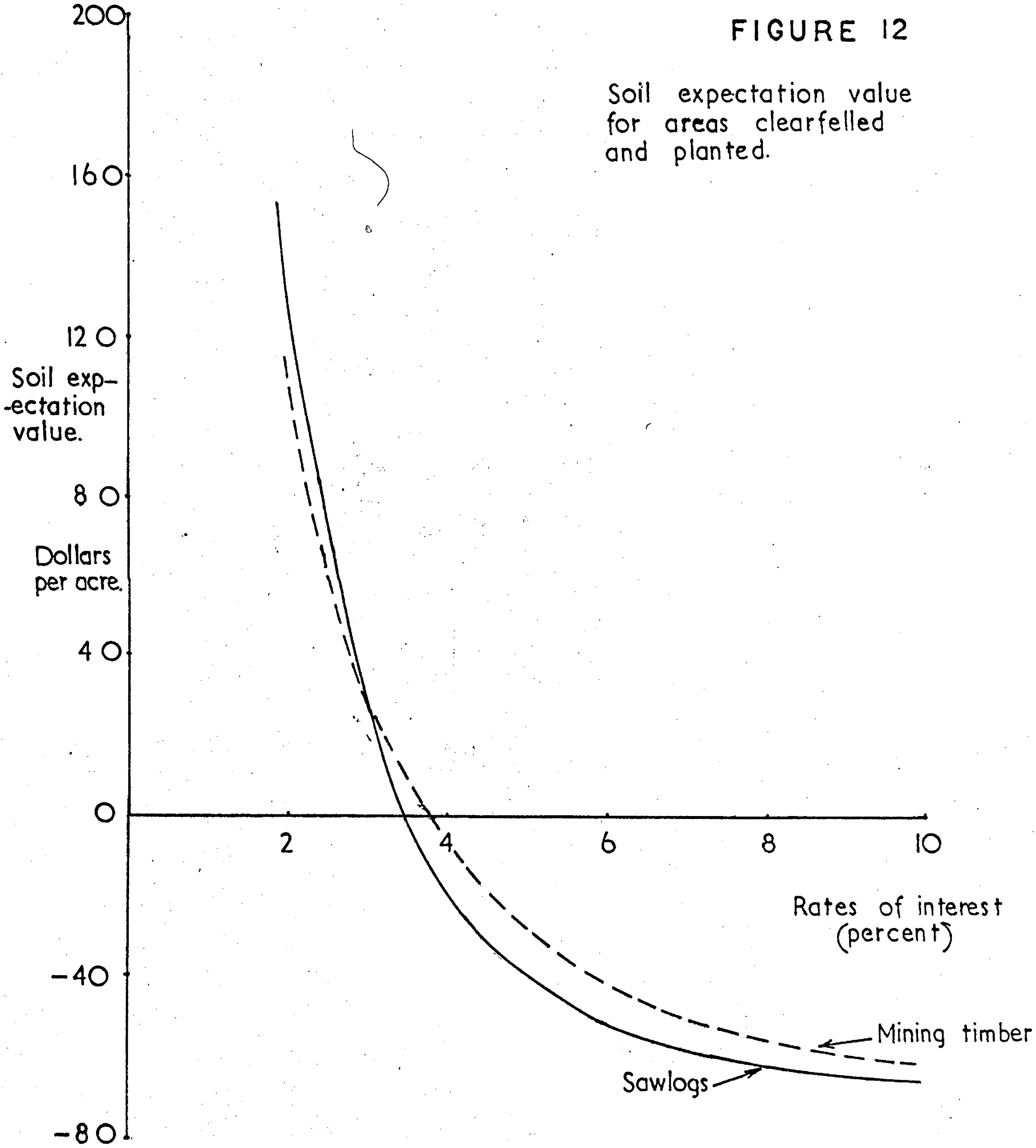
TABLE 39. Summary of soil expectation values.

	Rate of Interest (percent)					
	2	3	4	5	7	10
Sawlog 80 year rotation	132.22	24.66	-19.66	-40.91	-58.72	-66.6
Mining timber 40 year rotation	118.80	31.73	- 6.50	-17.65	-49.19	-61.5

With zero land cost 3.5 percent is earned for sawlog production and 3.8 for mining timber.

FIGURE 12

Soil expectation value for areas clearfelled and planted.



6.2 Financial Comparison of Irregular and even-aged forests.

Where selective logging and treatment has occurred in the past, good stocking permits the standing forest to continue as efficient forest capital. The often grouped nature of the advance growth allows application of the group selection system.

The comparison to be made for this forest does not only involve the opportunities for growth subsequent to regeneration but also includes the option whether the stand will be harvested or not. To embrace this option discounted net worth values will be calculated using an interest rate of seven percent. This rate is used as it is the current rate applied to Government borrowing. Opinion is developing that this rate is too low but this will not be discussed here.

The stand suitable for continued development by the group selection system is estimated, from the Benandarah C.F.I. data, to have a merchantable volume of 11,000 super feet and a basal area of approximately 80 square feet. The standing value of this forest is $160.00 per acre.

To simplify the calculations it is presumed there are four cutting cycles each of twenty years. One quarter of the average acre is cut and regenerated in the middle of each cycle. The establishment costs used in the clear felling example above will be used, the extra expense involved in regenerating small areas in group selection are compensated for by less difficult clearing. The yield at each cutting cycle mid point is assumed to be one quarter of the average standing volume. It will be removed as sawlogs; mining timber is not considered. During the four cutting cycles the merchantable mid point standing volume is anticipated to improve from 11,000 super feet per acre to 17,000 super feet per acre as a result of cull removal and improved stocking. The yields and their values are :

Age	Volume on average quarter acre	Value
10	2750	39.90
30	3250	42.10
50	3750	54.30
70	4250	61.50

After 80 years the forest is unlikely to continue its improvement but will remain producing 4250 super feet every 20 years, a M.A.I. of 217 super feet per acre per annum. The discounted net worth equation was modified for this infinite case.

Annual charges are again $0.50 per acre per annum.

The discounted net worth for the options open to management for the forest suitable for continued group selection are :-

(i) Forest clearfelled and replanted with the objective of 80 year rotations for sawlogs and mining timber produced as thinnings $101.28

(ii) Forest clearfelled and replanted with the objective of 40 year rotations for mining timber only $110.81

(iii) Forest continued by group selection system as described above $ 9.34

The discounted net worth is $91.94 greater for the clear felling and sawlog production (i) above; and $101.47 greater for clear felling and mining timber production,(ii) above.

6.3 Discussion.

When recreation uses require continuation of the better forests by group selection management the cost is the difference between the discounted net worth of the two management options. It is approximately $100.00 per acre in the example given which would approximate the Benandarah and part of the Kioloa area.

CHAPTER 7.

RECREATIONAL USE OF FOREST

7.1 Values of recreational use of forest land - General.

The features of the forest discussed so far involve the quality, structure and growth rates of the stands considered in the light of commercial wood production. The forests, however, have an increasing use for "products" where growth rates and tree condition are less important. This was heralded by Byles (1958) when he stressed the need for foresters to adopt a broader outlook on forest use.

The use of the forests for recreation is increasing rapidly as are the associated wild life values. People go to the forest for greater rapport with nature together with the obvious relaxation and pleasures derived from scenery. The individual tree quality is less important than the overall pattern and condition of the forest. A study by Rutherford and Shafer (1969) suggests for certain types of North American managed forest that the visitors and users are not concerned by logging. In the Australian Eucalypt forest, however, after logging and treatment the stands are greatly different from their original appearance.

High grading or selective logging is disliked least by people using the forest for recreation as after a small number of years the more obvious signs are covered and they do not know logging had taken place. Additionally access provided to allow logging permits the user to move about the forest. Without doubt a clearfell is useless for recreation. It is, however, advantageous for wild life conservation as the variation in habitat provided by well distributed blocks of clearfell increases feeding opportunities for many animals and birds which browse in the natural openings. The recreation value is low as heavy treatment prevents entry into the stand because of the presence of weeds, vines, debris and regeneration. People see it as destruction. This causes dislike and it is extremely hard to convince them it is not destruction, particularly when natural regeneration methods are used.

During a recent discussion I held with naturalists interested in the Kioloa forest the useless commercial timber concept of the residual stand was difficult to transmit as the differences in tree quality were unnoticed until a tree became wizened and gnarled. The idea of useful forest created to serve, in the long term, all the purposes required from the wildlife and recreation point of view was quite novel. This excludes the establishment years.

More recently recreational values of forests have received increasing attention from both within the forestry profession and from active conservation bodies. Rockefeller (1962) emphasised the need for and benefit of planning for outdoor recreation. Downes (1966) pointed out the bad public image created by vicious argument between groups professing interest in conservation.

The values gained from outdoor recreation in forest land are difficult to assess. Whilst recreation values may be assessed for special circumstances, the values for ordinary forest remain obscure. Market value is unsuitable as an estimate for recreation values in public lands (Knetsch and Davis, 1965). However, to overcome emotional issued imputed values may be derived. Three different methods are available;

(i) consumer surplus
(ii) monopoly revenue
(iii) visitor survey.

The last two approach the problem by estimating the level of attendance at progressively higher admission charges to simulate a market price. The consumer surplus assumes each visitor places an intrinsic unique, and somehow, measureable value on his visit. The method analyses expenditure patterns of visitors from varying distances and thus calculates a surplus from value of the visit less costs for the visit. Care must be taken not to compare the values achieved by different methods due to the different functions being measured.

Recognition of different uses for forest all within the recreational sphere, add to the difficulty of assessing values. Clawson and Knetsch (1966) classify the outdoor recreation into three groups; user oriented, resource based and intermediate. The user oriented are the high density readily available small recreation areas, the resource based are the unique natural areas often at distance from population, whilst in the third category, the intermediate, occur the natural environment uses common with day visitors.

Clawson and Knetsch (1966) describe a method derived from the established demand function and using a procedure where increases in costs are related to the number of visits. Proximity to population centres has a large influence and the number of alternatives and time taken for the visit are secondary influences.

In discussing the value of land used for recreation, Clawson and Knetsch (1966) point out the use of land for recreation may require sacrifice of other goods and services. The value of the sacrifice can be expressed by benefit cost analysis after a vlue is established for the recreational aspect. Ferguson and Greig (1971) provide an example based on the Australian situation. They use the consumer surplus method to calculate the demand function for visitor use at Mt. Macedon,Victoria. The value of the resource is then deduced and compared with the value of exotic and hardwood forest at the summit. The balance in this instance was strongly in favour of the recreational use and the continued policy of multiple use was supported. Forest management maintains a park like state enhancing the recreation value.

Unfortunately, similar studies for the common forests are not available. Visitor densities for recreation within the forest are not easily assessed and further study is needed. Visitors to forests are spread widely over vast areas and sampling is difficult. The consumer surplus technique, monopoly revenue and visitor survey all fail to recognise the exact part forest condition or character plays when assessments are made of the recreation value of a lookout, mountain range, canyon, gorge or beach. Therefore the recreational value of South Coast forest will be taken as the opportunity cost of timber values removed from the forest yield due to recreational use.

7.2. The values of South Coast forest for recreation.

The value of forest areas for recreation will be studied only for the Bateman's Bay to Termeil area (figure 2). Within the limits of this area recreation pressures have greatly increased in the past decade.

In each of the examples below the management considered best suited for timber production may require modification to provide for multiple use. If this modification causes production losses then the losses are a cost against multiple use. If however the recreational use of the area was sufficient to have the forest removed from timber production entirely, such as by revocation and re-dedication as State Park, the entire loss of timber values must be borne as the cost of recreation.

Three different forest recreation situations can be discussed:

7.2.1. Kioloa and Benandarah State Forests.

The sections of these forests east of the highway, between the highway and the ocean are considered first. The forests are of good quality on gentle topography and provide scenic access routes and a backdrop to the beaches. Very little active use occurs away from the roads. Visitors drive along the access roads either for pleasure or to reach the beaches. The proposed Murramurang State Park takes in the immediate backdrop to the beaches.

A large proportion of the forest has a vigorous, irregular stocking resulting from years of selective logging and silvicultural treatment. The stands are aesthetically pleasing and abound with wild life, both lyre birds and wallabies are common. The forest can be managed using a selection system, probably group selection, as the regeneration requirement will not disturb the aesthetic values of the forest. In other parts drastic treatment has already been carried out to rejuvenate the area. The even-aged forest resulting from the treatment can be developed in time into a selection forest.

A plan has already been developed to foster high recreation values along the major access routes using "zones of minimum disturbance". Similar restrictions have been applied along the boundary of the State Park. The acceptance of zoning formalises the multiple use policy for these parts of the forest. Figure 13 shows the method of zoning. The zones are :-

(a) <u>Zone of Minimum Disturbance</u>.

The areas within this zone are unlikely to be logged in the immediate future; but if logged, only very overmature trees and any badly damaged or dying trees should be removed. The full aesthetic qualities of such stands should be preserved. Dumping and loading of logs is to be avoided along road edges in this zone.

Areas included in this zone are -

(i) Forest along major access roads to beaches and Murramurrang State Park.

(ii) Blocks of forest between treated areas to serve as examples of forest types prior to logging and treatment.

(iii) Forest adjoining the shoreline.

(iv) A buffer strip adjoining Murramurrang State Park.

(b) Zone of Selection Logging.

"Selection logging" includes the zone where forest logged and treated in the past is still used for timber production whilst at the same time contributing to the natural appearance of the forest. It includes areas treated by both group selection and advance growth salvage methods.

(c) Zone of Unrestricted Forestry Activity.

The third zone is a temporary one, including forest where selection methods are inappropriate due to useless overstorey. A system approaching a clear felling will be used to return the stand quickly to productivity. This type of treatment will only be carried out for the next few years to rejuvenate the stand. It is proposed to manage the forests established in this way by selection methods.

For the untreated, minimum disturbance zones, the discounted net worth for timber production is virtually zero. Therefore the cost of reserving these areas for their recreational value is $160.00 per acre. In the selection management of the Kioloa and Benandarah S.F. areas the discounted net worth is $9.34 and the difference between the discounted net worth for clearfelling and planting and group selection is $91.94. This value can be regarded as the cost to production forestry of restricting the management to group selection to preserve its recreational quality. For the time being no loss in timber production value is involved in the heavily treated forest as it is of little value for recreational use although wild life occurs in these areas in high numbers.

Timber production at 200 su.ft. per acre per annum is lower in the selection forests than in the proposed even-aged forests where the M.A.I. is 500 to 600 super feet per acre per annum. The opportunity for increased production and the ensuing community benefit from timber is restricted by multiple use, but additional benefits will be created by increased tourism and recreation.

7.2.2. Forests adjacent to the Clyde River.

Areas of State Forest adjoin both tidal and freshwater sections of the Clyde River. They offer an opportunity for combined land recreation and water sport and though little used at present can be expected to attract more attention in the future.

Selective logging has occurred over most of the forest adjacent to the river but the present forest is not vigorous. Selective logging in future is unlikely to lower production.

These areas have little importance for timber production and can be considered primarily as recreation forests.

7.2.3 Forests adjacent to inland National Parks.

The third area lies adjacent to the Morton National Park and its anticipated southern extension to include the Budawang Range. The National Park has a wilderness character and only minimal vehicular access. The sandstone plateaux and sheer rock faces including the Castle, Mt. Talaterang and the Pigeon House are viewed, except by the most hardy walkers, from roads and trails associated with forestry and fire protection activities.

Recognition of this use of the forest will encourage management to site roads where least likely to disrupt natural panoramas and vistas and to modify logging schedules to minimise gaps and scars. Additional costs associated with road relocation and restriction of logging yields are a debit against multiple use. However, very little consideration of this nature has been given in the past. Low standard roads and selective fellings become overgrown and obscured within a few years.

Vantage points, lookouts, and picnic places have been established as the opportunity allowed. Figure 14 shows a typical view of the Castle from one of these. Fire places, tables and toilets are now required.

Once again the costs are difficult to assess. Alteration to road locations may increase roading costs by up to $3000 per mile. Snigging costs will also increase with the restriction of dump sites away from ridge tops and reduced volumes at each operation. Until fire control is improved the area will remain too remote and too subject to fire risk to justify investment in regeneration. Therefore retention of useful trees is necessary to prevent the build up of unsaleable material, this will restrict the volume available for logging. The usefull trees retained will allow part of the normal increment to be placed on desirable trees. Regeneration groups will be fostered by log marking.

FIGURE 14.

A view from Yadboro S.F. toward the Castle, Byangee Walls and Mt. Talaterang.

The undulating to hilly country in the middle of the picture is Yadboro S.F. Much of this area has been selectively logged in the past ten years.

7.3 Summary.

Losses in the order of $100 per acre from the present net worth of the timber estate will occur if areas of the good quality forests adjacent to the coast are removed from timber production in favour of recreation. If the same areas are restricted to selection felling the loss is approximately $90 per acre when compared to the opportunity for clearfelling and replanting.

In the western forests of the study area, the adjacent National Park offers the opportunity for active multiple use of the forest on the Park perimeter. No regeneration treatment is anticipated for this area at present. The costs of multiple use are the increased logging and roading charges due to restrictions intended to minimise the disruption of the "natural" appearance.

CHAPTER 8.

THE MANAGEMENT DECISION.

The needs for recreation facilities in the forests have increased and can be expected to increase rapidly in the future. Clawson and Knetsch (1966) report a ten percent per annum increase in outdoor activities in the U.S.A. and Ferguson and Greig (1971) estimate an average 6 percent increase for the Grampians area in Victoria. The pressure for outdoor recreation becomes greater with increased leisure time and annual salary (Douglass 1969).

Recognition of this trend is necessary if we are to plan for balanced community needs in both timber and recreation. The significance of "balanced" must be stressed for while recreation gains momentum we must remember that the present well being of local communities depends upon the harvest from the forest. Timber takes time, a long time, to grow and continued supply is essential if processing plants are to remain viable.

The Bateman's Bay area is ideally situated to supply both recreation and timber. Overseas experience has shown approximately 100 miles to be the limit for intermediate or day-use recreation. These forests can thus serve both Canberra and Wollongong (see figure 1.) Ovington (1968) stressed the value of forests near to population centres, and so increased recreational use can be expected in the forests of the Bateman's Bay area. Pressure groups interested in national parks, conservation and outdoor recreation have become both active and vocal in these cities recently. Murramurrang State Park must owe its origin, at least in part, to the influence of these groups who are even now pressing for revocation of more forest and dedication of further State Park. There is a possibility that more and more land will be included in national parks as a result of these pressure groups and the political influence they exert. Existing State Forest is not being used to the fullest extent for recreation at present so there is an argument for deferring further reservation of productive forest as national parks until a real need is demonstrated.

These areas could be managed for multiple use, both recreation and production, using a group selection system in what would be essentially an irregular and uneven aged forest. This type of forest has a pleasant appearance lacking large clearfell areas which have little aesthetic appeal. There are many reasons why timber production on these forests should be maintained but the increasing demand for public recreational use is recognised. In Chapter 6 it has been shown how this silvicultural system, if adopted, would mean a considerable loss of financial return to the Forest authorities. This loss must be considered as the cost of multiple use for recreation and forestry.

It must also be made clear to the public that those forest areas between Bateman's Bay, Termeil and east of the highway, which many wish to include in Murramarang National Park, is ~~all~~ mostly treated forest, managed for many years past as an irregular, well stocked forest using a group selection system. If this forest is to retain its appeal it must continue to be managed in this way otherwise it will deteriorate into an old growth area. The need for intensive fire protection must also be emphasised. A viable forest service system within the area will serve this purpose to greatest effect.

In this thesis it is shown the spotted gum forests have a reasonable rate of growth when well managed. Volume increment rates in excess of the national average figures of six cubic feet quoted by Jacobs (1955) and five to ten cubic feet quoted by Curtin (1970) are recorded. This improved yield will help to satisfy the dramatically expanding mining activity on the southern coalfields. Considerable areas of the spotted gum forests should be managed initially on the more profitable clear fell system. Those sections of the forest where public recreation will increase can be converted gradually to irregular forest with aesthetic appeal. The nation can ill afford to tie up large tracts of productive forest as single use recreation or conservation areas. To do this will mean an increase in imports of timber and wood products, and for an increased investment in big production plantations. Therefore there is very good reason to retain these forests for multiple use.

To retain the spotted gum forest for both production forestry and public enjoyment there are responsibilities and restrictions necessary which must be understood by all parties.

The forester must realise his responsibility to manage the forest, not just to mine the timber. The location of roads for maximum recreation benefit or minimum disturbance to the forest's scenic character, along with the protection of fauna and their habitat are some important management aspects. These will place restrictions on forest operations and require greater expertise and increased planning.

The public must be made to appreciate, through careful publicity and education, that the forest has a multiple role to fulfill and certain aspects of forest operations must be tolerated. A limited degree of major disturbance is necessary to extract logs and to establish regeneration, but the public must be persuaded this is essentially short term - 2 or 3 years only, before natural process of nature will obscure these scars. Presence of a viable forest unit is necessary to maintain roads, and provide protection and this will be paid for by the produce of the forest, and will not be a total cost to the taxpayer.

The spotted gum forests can be managed for multiple use. There will be restrictions on all parties involved but with careful planning and public awareness of all aspects this should be a desirable objection in the national interest.

REFERENCES.

Anon. 1970 Water resources of the Tuross Valley. Report No. 20 in a survey of thirtytwo N.S.W. river valleys. N.S.W. Water Conservation and Irrigation Commission.

Anon. 1970 Water resources of the Clyde Valley. Report No. 21 in a survey of thirtytwo N.S.W. river valleys. N.S.W. Water Conservation and Irrigation Commission.

Baur, G.N. 1957 Nature and distribution of rain-forests in New South Wales. Aust.J.Bot. 5 (2) 190-233.

Baur, G.N. (Ed.) 1965 Forest types in New South Wales. Forestry Commission of N.S.W. Research Note No. 17.

Beadle,N.C.W., and A.B.Costin,1952. Ecological classification and nomenclature. Proc.Linn.Soc. N.S.W. 77:61-74

Blakeley, W.F. 1955 A key to the Eucalypts, 2nd edition. Commonwealth of Australia Forestry and Timber Bureau, Canberra.

Byles, B.U. 1958. The responsibility of the forestry profession towards the management of forested lands for the purpose of protection. Aust.For. 22: 55-58.

Clawson, M. and J.L. Knetsch,1966. Economics of outdoor recreation. John Hopkins Press,Baltimore. 328 pp.

Cremer, K.W., 1960 Eucalypts in rainforest. Aust. For. 24: 120-126.

Curtin, R.A. 1963 Ideal stocking for maximum production in an irregular blackbutt forest. Aust.For. 27: 121-127.

1968 The growth of spotted gum stands - an internal report of the Forestry Commission of N.S.W.

Curtin, R.A. 1969. Growth analysis of a mixed Eucalypt forest. Unpublished internal report of Forestry Commission of N.S.W.

1969a. A provisional yield table for even-aged stands of blackbutt. Forestry Commission of N.S.W. Tech. Paper No. 15, 9pp.

1970. Increasing the productivity of Eucalypt forests in N.S.W. Aust. For. 34: 97-106.

Douglass, R.W. 1969. Forest recreation. Permagon Oxford 336 pp.

Downes, R.G. 1966. Conservation of natural resources. Proc. School for Foresters at Univ. of New England. 1966.

Ferguson, I.S. and P.J.Greig, 1971. What price recreation. Proc. 6th Conf. Institute of Foresters Thredbo, 1971.

Florence, R.G. 1963. Vegetational pattern in east cost forests. Proc. Linn. Soc. N.S.W. 88: 164-179.

1964. Edaphic control of vegetational pattern in east coast forests. Proc. Linn. Soc. N.S.W. 89: 171-190.

1965. Some vegetation - soil relationships in the Blackall range forests. Aust. For. 29(2): 105-118.

1968. The role of blackbutt in east coast forests. Aust. For. 32: 118-127.

1969. Conservative silvicultural practice in irregular blackbutt forest. Cw'lth.For.Rev.49: 86-93.

1969a. The application of ecology to forest management with particular reference to Eucalypt forests. Proc.Ecol.Soc.Aust.4: 82-100.

Florence, R.G., G.M. Shea and R.E. Pegg. 1970.
Development of a logging schedule for spotted gum (Eucalyptus maculata) forest. Comm. For. Rev. 49: 235-244.

Floyd, A.G. 1965. Tractor versus fire in moist hardwood regeneration. Proceedings 4th Silv. Res. Officers Conference, Forestry Commission of N.S.W. Tech. Paper No. 10.

Gilbert, J.M. 1963. Fire as a factor in the development of vegetational types. Aust.For. 27: 67-70.

Grose, R.J., F.R. Moulds and M.G. Douglas, 1964.
Aerial seeding of alpine ash. Aust. For. 28: 176-186.

Hanson, A.G. 1965. Effects of silvicultural practices on logging costs. Aust.For. 30: 38-42.

Henry, J.L. 1961. Management of forests for commercial purposes. Paper for "Men of the Land" symposium on Tree and Forest conservation.

Henry, J.P. 1965. Control burning in blackbutt (E.pilularis forest on Manning River N.F. Aust.For.Res.Vol.1

Henry, N.B. 1960. The effect of silvicultural treatment on the production from native forests. Aust.For. 24: 30: 45.

Henry, N.B. and R.G. Florence, 1966.
Establishment and development of regeneration in spotted gum - ironbark forests. Aust.For.30: 304-316.

Holmes, D.A. 1968. Blackbutt plantations on the N.S.W. North Coast. Paper to 5th Inst. of For. Conf. Perth 1968.

Hoschke, F. 1967. Kendall management inventory, an internal report of the Forestry Commission of N.S.W.

Jacobs, M.R. 1954. Silvicultural problems in the mixed Eucalypt forest of the East Coast of Aust. Emp. For. Review. 33: 30-38.

1955. Growth habits of the Eucalypts. Forestry and Timber Bureau, Canberra,262pp

Knetsch, J.L. and R. Davis,1965. Comparison of methods for recreation evaluation in "Water Research" ed. Kneese and Smith, John Hopkins Press, Baltimore, 1965.

Lugton, G.S. 1968. Economics of plantation. Paper presented at the "School of Forestry Economics" held at the Univ. of New England. p.113-120.

McArthur, A.G. 1967. The influence of fire on productivity of hardwood forests in Australia. Aust.For.Res. 3: 24-35.

McColl, J.G. and F.R. Humphreys,1967. Relationships between some nutritional factors and the distribution of Eucalyptus gummifera and Eucalyptus maculata. Ecol. 48(5) 766-771.

McGrath, K.P. 1965. Approaches to the solution of the problem of future wood supply. Aust. For. 199-207.

Mount, A.B. 1964. The interdependence of eucalypts and forest fires. Aust. For 28: 166-192.

Northcote, K.H. 1965. A factual key for the recognition of Australian soils. C.S.I.R.O. Div.Soils Report 2/65 Adelaide.

Ovington, J.D. 1968. Considerations of Forest Productivity. Proc. 5th Institute of Foresters Conf. Perth 1968.

Phillis, K.J. 1970. A computer program to calculate individual tree volumes by the "Graphical Method." Unpublished roneo.

1971. Unpublished Ph.D. thesis, Australian National Univ.

Podger, F.C. and G.B. Peet, 1965. Some effects of fire on the growth of jarrah. 4th Conf. Inst. For. Hobart 1965.

Rockefeller, L.S. 1962. The future of outdoor recreation. Jour. of For. 60: 521-524.

Rutherford, W. and E.L.Shafer,1969. Selection cuts for increased natural beauty. Jour. of For. 67:881:885.

Smith, D.M. 1962. The practice of silviculture. 7th ed. John Wiley and Sons, New York, 578 pp.

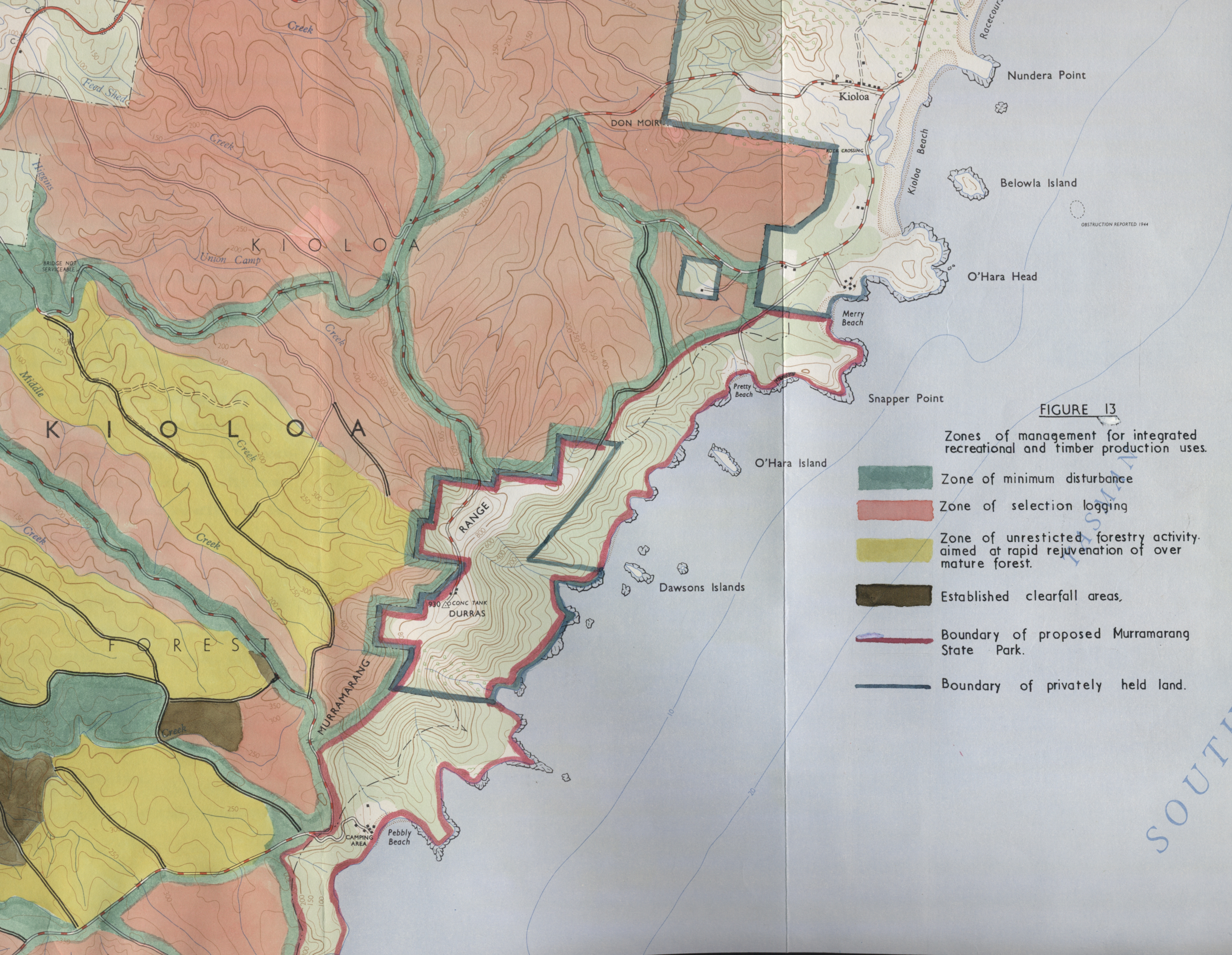
Stephens, C.G. 1956. A manual of Australian Soils. C.S.I.R.O., Melbourne.

Van Loon, A.P. 1966 Investigations in regenerating the tallowwood - blue gum forest type. Forestry Comm. of N.S.W. Res.Note No.19.

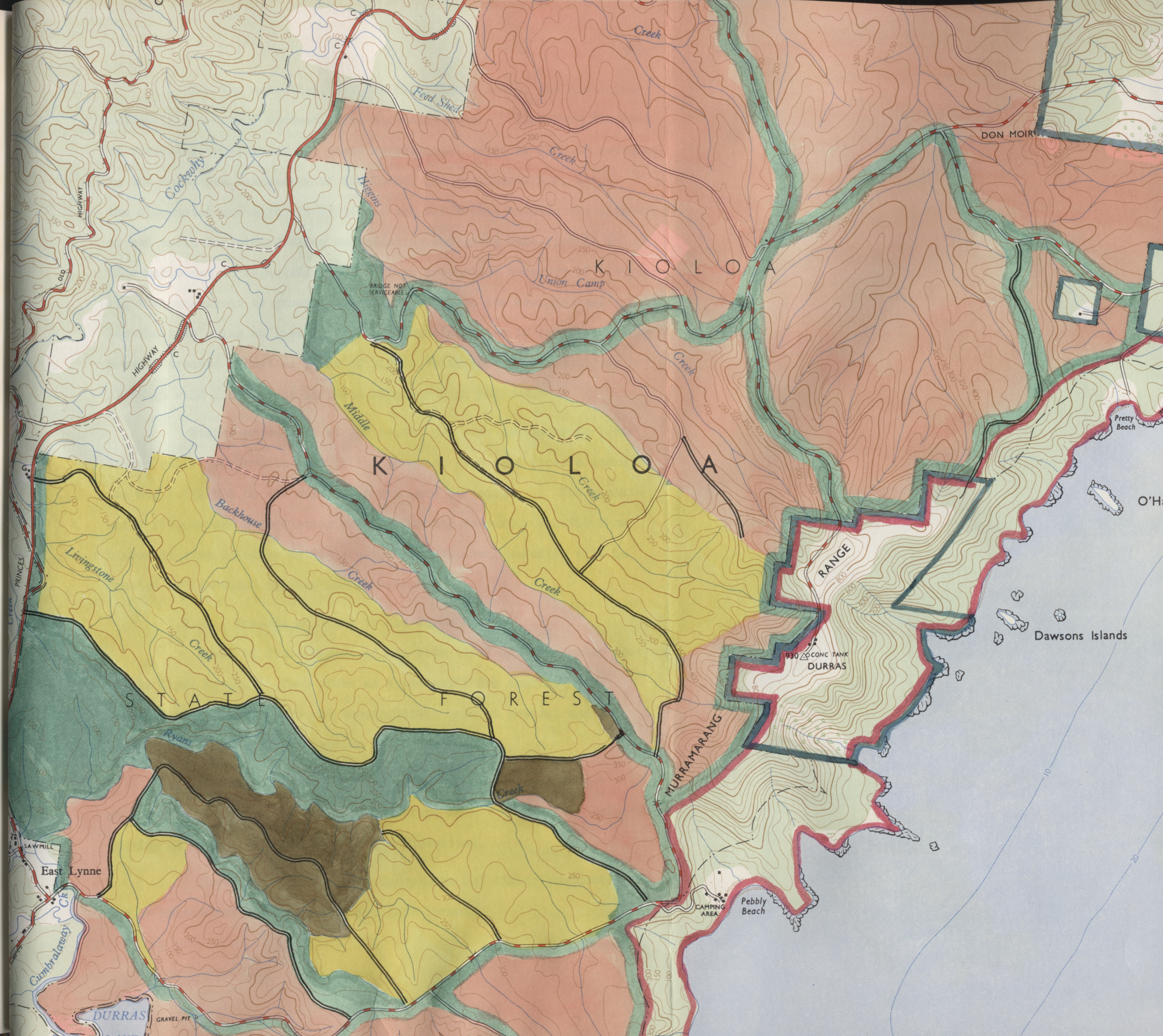
Walker, P.H. 1960 A reconnaissance of the soils and land use of part of the South Coast of N.S.W. Soils and land use series No. 38 C.S.I.R.O., Melbourne.

Watt, A.J. 1967 A comparison of some basic concepts of rotation age. Aust. For. 31:275-286.

Winterhalder, E.K. 1963 Differential resistance of two species of Eucalyptus to toxic soil manganese levels. Aust. J. Sci. 25: 363-364.



Nundera Point
Kioloa
Kioloa Beach
Belowla Island
OBSTRUCTION REPORTED 1944
O'Hara Head
Merry Beach
Pretty Beach
Snapper Point
O'Hara Island
Dawsons Islands
DON MOIR
ROCK CROSSING
KIOLOA
Union Camp
BRIDGE NOT SERVICEABLE
Feed Shed
Higgins
Creek
Middle
KIOLOA
FOREST
RANGE
CONC TANK
DURRAS
MURRAMARANG
CAMPING AREA
Pebbly Beach
TASMAN
SOUTH
FIGURE 13
Zones of management for integrated recreational and timber production uses.
Zone of minimum disturbance
Zone of selection logging
Zone of unresticted forestry activity aimed at rapid rejuvenation of over mature forest.
Established clearfall areas.
Boundary of proposed Murramarang State Park.
Boundary of privately held land.



KIOLA
KIOLA
STATE FOREST
Creek
Feed Shed
Cockwhy
Higgins
Creek
OLD HIGHWAY
HIGHWAY
Union Camp
BRIDGE NOT SERVICEABLE
DON MOIR
Middle Creek
Backhouse
Creek
Creek
Livingstone
Creek
PRINCES
Ryans
Creek
RANGE
MURRAMARANG
930 CONC TANK
DURRAS
Pretty Beach
Dawsons Islands
CAMPING AREA
Pebbly Beach
SAWMILL
East Lynne
Cumbralaway Ck
DURRAS
GRAVEL PIT